JOURNAL
OF
THE FRANKLIN INSTITUTE
DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXXIX MAY, 1915 No. 5

CONDITIONS AFFECTING THE SUCCESS OF MAIN LINE ELECTRIFICATION.*

BY

W. S. MURRAY,

Consulting Engineer, New York, New Haven and Hartford Railroad Company.
Member of the Institute.

BEFORE touching upon the conditions affecting the success of main line electrification, perhaps it would be best to address ourselves to the question as to what constitutes success. A successful electrification may be considered as such from several viewpoints, and this leads to the necessity of a clear understanding with regard to projected results, both on the part of the railroad and the public.

A successful electrification means, of course, successful transportation by electric motive power. Classifying success into its broadest terms, an electrification may be:

1. A success for the public.
2. A success for the railroad.
3. A success for both the public and the railroad.

Naturally the greatest objective is the attainment of No. 3 of the above classification.

The railroad is vitally interested in the pronouncement by the people as to whether its electrification is successful or not, and, while the viewpoint of the railroad is identical with that of

* Presented at the joint meeting of the Institute and the Philadelphia Section, American Institute of Electrical Engineers, held January 20, 1915.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

Copyright, 1915, by THE FRANKLIN INSTITUTE.

the people throughout their range of vision, looking at it, however, from the purely railroad side, a successful electrification, besides this, must answer the dictates of good business, which in turn are governed by the rules of economic consideration.

In latter times the tremendously decreased gross earnings and a complementary increase in operating expenses have so greatly reduced the net incomes of the railroads that the public have awakened to the fact that they are staggering under a financial load which, if not modified or alleviated in some way, will shortly make receivership the rule rather than the exception.

A few years ago a movement was started by the public to require the railroads to electrify, this being directed towards roads of large size with their attendant city yards and terminals. There were two principal and logical factors against the justice of this demand, the first being that at that time there was very little statistical information as to form, application, and economic result of electrification; and, second, due to the extremely grave financial situation as above described, it was patent that the railroads could not possibly carry the increased financial obligations that such a demand necessitated. The public were thus brought face to face with the undeniable conclusion that they were demanding something impossible, and so there has been a pause on their part, which has indeed been gratefully received by the railroads of this country. Let it be said that this very pause will later shed its dividends over many, for during this time the few railroads that had committed themselves to electrification have had an opportunity to study it in all of its important details and ramifications, and later, after an adjustment has been made whereby the solvency of the railroads of this country is guaranteed by a proper relation between transportation rates and operating expenses necessary to the safe conduct of their business, with enough left over to provide a reasonable return on a fair valuation of the property in use, then, and only then, will the railroad companies be able to do what to-day they cannot, namely, attract new capital required for electrification; and so, while a reference to this matter may be slightly off the subject of this paper, yet I cannot but take this opportunity to say in the abstract that this is indeed an important condition precedent to successful electrification.

The pause has given us a chance to learn many things about electrification. I do not believe that I would be conveying informa-

tion to many who have studied the subject to say that there are probably one hundred places at this moment where conditions are such as to ensure successful electrification. For example, there is one situation I have in mind where an expenditure of $5,000,000 would yield beyond peradventure a return of 20 per cent.; this as measured against the present steam operation of the territory contemplated for electrification, and yet in the same breath it might be said that if the yield could be shown to be 40 per cent. instead of 20 per cent. the electrification of that territory would be denied, and rightly, too. Why? Because, for roads sufficiently large to consider electrification, a sum of this size is small in comparison to their existing capital investment, and a proper relation must first be established between capital already invested and the return upon it before further charges against capital account are made, no matter how attractive the return on the proposed betterment may be.

Quite a number of trunk line railroads, both in this country and abroad, have been studying electrification. The New York, New Haven and Hartford Railroad has not only been studying it most carefully, but has also had the opportunity of assembling data from the practical experience of operation with a range of application that includes all classes of transportation. Millions of ton miles in these several services have been actually recorded in the logs of the road's operation. In passenger service alone for the year 1913, 2,182,000 electric passenger locomotive miles were recorded, which alone would represent approximately 600,000,000 ton miles. The part of the New Haven system that has been electrified constitutes its most important division, extending from New Haven to New York, and on its main line, yards, sidings, and spurs every class of railroad movement is being daily made by electricity. A brief physical description of this division may be as follows:

Route mileage electrified, 73 miles, of which 61 is of four tracks and 12 of six tracks, thus giving a total main line mileage, measured in single track, of 316. To this may be added 184 miles of yards, sidings, and spurs, thus making a grand total, measured upon a single-track basis, of 500 miles. It is of interest to note that of the yards electrified one includes 35 miles, the other 25 miles.

Electric power is supplied to this extensive mileage from a

single station, centrally located, but which, in a short time, will be supplemented by other supplies to be applied at the east and west ends of the electrification zone. There are 100 passenger, freight, and switching electric locomotives, and 69 multiple-unit cars. One main electrical shop has been completed, the capacity of which permits the maintenance and repairs of the above-mentioned electric motive power. Facilities for inspection of electrical equipment are also provided at various points in the electrification zone, the more important points being, of course, at termini.

To date, over $15,000,000 has been expended on this electrical transportation plant as above described. While such a figure represents the cash outlay, there have accrued to its appropriation accounts, during the process of construction, large credits for steam equipment replaced, as, for example, the 150 steam locomotives which have been transferred to other parts of the New Haven system, and the steel bodies of the multiple-unit equipment, which would have been purchased even had not the electrification been undertaken.

Descriptive of the electric movement on the New Haven electrification zone, the following facts with regard to passenger, freight, and switching service may be of interest:

Passenger.

At the present time all passenger service west of Stamford, Conn., is electrically operated. For the winter time-table now in effect, excluding Sundays, the schedule calls for 68 trains per day into Grand Central Terminal, two through trains terminating in Harlem River Station and the same number of trains out of the Grand Central Terminal and Harlem River, or a total of 140 trains per day.

The Harlem River Branch service includes 19 trains each way per day, except Sundays, between New Rochelle and Harlem River.

On the New Canaan Branch 16 trains are operated each way between Stamford and New Canaan.

This makes a total week-day schedule of 210 trains per day. Additional trains in and out of Grand Central Terminal are operated on Saturdays, and extra trains are also run on the Harlem River Branch on Sundays.

Of the 70 through trains per day between Grand Central

Terminal, or Harlem River, and New Haven, 46 are electrically operated the entire distance, steam locomotives being used between New Haven and Stamford on the remaining 24 trains.

Of the 210 trains per day, 114 are hauled by electric locomotives, multiple-unit equipment being used on the remaining 96 trains.

Forty-eight A.C.-D.C. locomotives are used in passenger service. The multiple-unit equipment at the present time comprises four A.C. motor cars, 21 A.C.-D.C. motor cars, and 46 trailers.

The average number of electric train miles per day is about 6600, of which 1400 are made by multiple-unit equipment, the remaining being trains hauled by electric locomotives.

The passenger locomotives make an average of 8200 miles per day, some of the individual locomotive mileages being as high as 450 to 500 miles. Forty-one of the 48 passenger locomotives used in A.C.-D.C. service were originally designed to haul trains of 200 tons trailing weight in local service, 250 tons in local express service, and 300 tons for through express service between New York and New Haven. At the present time two of these locomotives are used only on through express trains where the trailing weight exceeds 390 tons, and two locomotives may also be used on heavy local trains.

New flash boilers have recently been installed in these 41 locomotives, of increased capacity, to provide for steam heating of through passenger trains between New York and New Haven. This is accomplished successfully. Through service between New York and New Haven was inaugurated in June, 1914, and these locomotives easily make their running time in express service.

The remaining seven A.C.-D.C. passenger locomotives were originally designed to haul local trains of 350 tons trailing weight or express trains of 800 tons trailing weight at a maximum speed of 45 miles per hour. In actual service these locomotives attain a maximum speed of 55 miles per hour.

The multiple-unit motor cars make an average of 2100 miles per day. The proportion of trailers to motor cars for A.C.-D.C. equipment averages two trailer cars to one motor car. On the New Canaan Branch the proportion is one trailer car per motor car, while on the Harlem River Branch about one-half the trains have two trailers per motor car, the remaining trains consisting of a motor car and one trailer.

Of the 96 trains operated per day by multiple-unit equipment, 38 are Harlem River Branch locals, 32 are New Canaan Branch locals, and the remaining 26 are either locals or local express trains between New York, New Rochelle, Port Chester, Stamford, and New Haven.

Freight.

Thirty-six A.C. locomotives are used in freight service. These are geared locomotives of 1400 horse-power each and designed originally to haul a trailing load of 1500 tons in through service at 35 miles per hour, although they are used at times for heavy passenger service in the A.C. zone during the summer months, when heating of the trains is not required. Some of these A.C. locomotives are used in transfer service between Oak Point and Westchester freight yards on the Harlem River Branch, others in way freight and switching service, but the majority are used on through freight trains between Harlem River and Bridgeport or New Haven. Outside of the fast freights, which are usually under 1500 tons trailing weight, most of the freights are hauled by two locomotives, the trailing tonnage averaging from 2500 to 3000 tons, although, as an experiment, tests have been made in using three locomotives with trains of over 200 cars and 4500 tons trailing weight.

About 20 freight trains are hauled daily at the present time by electric locomotives between Harlem River and Bridgeport or New Haven.

Switching.

Electric switchers are used in the three main switching yards on the Harlem River Branch, located at Westchester, Oak Point, and Harlem River; likewise at Stamford, Port Chester, New Rochelle, Mt. Vernon, and at Van Nest, the latter yard being principally used for storage.

At Oak Point and Harlem River the switchers are used principally for unloading and loading floats and making up trains. One switcher was placed in service in March, 1911, at Stamford, and the remaining 15 have been in operation since September, 1912. They have been highly successful in operation, and their reliability is evidenced by the fact that to date there has been only one case of grounded main motor, although the 16 locomotives have made approximately 50,000 miles each. Some of these locomotives have been at times in continuous service 24 hours per day

for 30 days, the only attention received being the renewal of blower or compressor motor brushes, or contact shoe of pantograph trolley at such times as change was made of the operating crew.

Four of these electric switchers have been found to do about the same work as six of the steam switchers, which they have displaced, principally on account of the fact that the electric switchers can be used almost continually with no layover periods. On account of the simplicity of the equipment on these locomotives, used only on A.C., compared to the more complicated equipment used on the A.C.-D.C. locomotives, no trouble has been experienced in breaking in new men, and, as a rule, the engineers need comparatively little preliminary instruction when being transferred from a steam locomotive to an electric switcher.

Mercury Rectifier Car.

For some time a motor car has been in service which has been equipped with a Westinghouse-Cooper-Hewitt mercury arc rectifier and four 250-horse-power motors. After a period of experimental runs on the Harlem River Branch, this car was placed in commercial service on the New Canaan Branch on September 16, 1914, hauling two trailers, the weight of the trailing load being 76 tons. In this service the motor car has been making an average of 240 miles per day. During the time the car has been in commercial service two delays due to failure of the equipment on the motor car have been recorded—one of three minutes on October 13, due to poor contact of a control interlock finger, and one of sixteen minutes on October 16, due to a broken belt on the circulating water pump.

In 1905, when it became necessary for the New Haven Road not only to actively consider electrification, but promptly decide upon the system to be used, as there was but a scant two years left between that time and the date set by the decree of the New York Court for all New Haven and New York Central trains to operate by power other than steam through the Park Avenue Tunnel, a careful study into the conditions surrounding the New Haven requirements pointed to the necessity of a system different in principle and arrangement to that which had been decided upon and very nearly completed by the New York Central Company—not that the New York Central Company had not made a choice of system which was entirely correct, but because the New Haven

conditions were so entirely different from those of the Central. If we regard the New Haven electrification a success, here we must first note conditions that had to be reckoned with to ensure that success.

It was plain to the engineers who had studied these conditions that even in that early day, when the direct-current, 600-volt, third-rail system was at the height of its efficiency and popularity, it, when examined upon an economic basis, would fail by far in the result that would be secured in the use of the high-voltage, single-phase system.

In those days our experience with the A.C. system was *nil;* a clear vision as to the correctness of its principles, however, more than replaced this lack of experience. To many these were strange arguments to use against a well-tried-out and accepted system, and, while deeply sensible of a period both difficult and trying to the operators of the road, the burden of this decision had been made light by a willingness on the part of all to take a perspective rather than a foreshortened view of the situation as it has gradually worked its way out of its initiative troubles.

A storm of criticism from all parts of the world assailed our conclusion. As this, however, is ancient history, to say more along these lines would be to say less. This paper, however, might lack a detail not to mention the real reason for which a paper, entitled "The Log of the New Haven Electrification," presented in 1907 before the American Institute of Electrical Engineers, was written. It seemed to the writer that the thick layer of criticisms shortly after electrical operation was inaugurated, on top of the number that had been received before, required that the discussion be held down to the actual facts in the case, and, knowing that the principles upon which the New Haven electrification was based could not be assailed, and that the log sheet of operation, bad as it was, was merely a reflection of the minor details common to initiative in all new undertakings, it were best to write a paper of the faults that had appeared and the methods used for their correction. This had the desired effect, as the discussion since then has been held within the facts.

It took not a great while to determine upon and eliminate the causes incident to the failures which reflected deleteriously upon the service of the road, and, while the reliability of operation in the electrical zone rose to some three or four times that of the

steam operation it replaced, it was not then or even now what it will ultimately be. At this point we touch upon one of the conditions to be satisfied in order than an electrification may be called a success; namely, reliability of service.

The replacement of a steam service which had never been criticised, by an electrical one of increased reliability, naturally brought the pronouncement of success by the public. Indeed, since those first days after the elimination of the troubles which assailed us in our initiative operation there has never been anything other than a favorable comment, both on the part of the public and the technical press. Naturally this was most encouraging to the new Haven engineers.

About two years following the presentation of "The Log of the New Haven Electrification" the writer ventured a second paper, entitled "Electrification Analyzed, and Its Practical Application to Trunk Line Roads, Inclusive of Freight and Passenger Operation," this also being under the auspices of the American Institute of Electrical Engineers, the intention being to present such electrification construction and operating data as he had collected to date, the object of the paper being to show the adaptability of electricity to extensive trunk line movement in all of its branches, covering passenger, freight, and switching on terminal and main line tracks.

In presenting the paper the writer purposely avoided a reference to comparative costs of operation between steam and electricity for two reasons: The first, because of the fact that only a part of the whole division was electrified, and an extremely expensive interchange of steam and electric operation had to be maintained, necessitating expensive duplications and special arrangements which would not have been common to either system had one or the other been used in its entirety upon the whole division. The second had reference to the matter of construction costs, which were exceedingly high in the case of the original electrification between Woodlawn and Stamford—the first undertaken. I am sure it will be of interest to state that in the original electrification the unit cost in 1907 for the four-track overhead system was just double the amount expended on the four tracks recently completed in the section between Stamford and New Haven.

In the discussions before the American Institute of Electrical Engineers and the American Society of Civil Engineers repeated

requests were made for a presentation of the construction and operating costs in connection with the New Haven electrification. For the reasons above cited, and for the fact that the New Haven electrification was decidedly handicapped in being required to build its motive power equipment to operate either with alternating current or direct current, the writer concluded that the time had not arrived where a presentation of these details would serve a useful purpose. Especially was this true in the bitter war that was being waged by parties who were prone to look upon the single-phase system of traction as deterrent to the application of the "more reliable D.C. third-rail system"—then in the flower of its youth, but since gone to seed! (I, of course, have reference to trunk lines.)

Here was the problem the engineers of the New Haven Road had placed before them: the consideration of an electrification, the demands upon which would be far beyond any other hitherto constructed or contemplated. The conditions and principles applying to the past and smaller electrifications did not apply to it. Which were to control—the correct principles with the failures always common to initiative, or the wrong principles with a sureness that the service for possibly a number of years would be of a more reliable character? Some of our friends in the technical press have been good enough to say some kind things with regard to the courage of our convictions. It did not take a very great deal of courage to do the right thing, and it cannot be denied that right principles should always govern.

Naturally, ten years of almost undivided attention to electrification work have brought a better knowledge as to how powerhouses, lines, locomotives, and shops should be constructed, and I do not believe I overstate when I say that the electrical plant the New Haven now possesses could be reproduced, and with far better operating results, at certainly not more than 60 per cent. of its original cost, but, notwithstanding this, when the electric division is on a 100 per cent. electrical basis the economic return will be sufficient to justify the electrical expenditure to date.

The recent decision as to choice of system on the part of the Pennsylvania Railroad in favor of single phase for the proposed electrification on its main line between Philadelphia and Paoli, this action being a forecast of the system to be employed in the event of the future financial situation permitting electrification

between New York and Washington, was one of no small consequence and pleasure to those who had been toiling to establish a correct application of electrification to trunk line territory.

To those who every day had been in close association with the practical workings of this system initially installed on the New Haven, failures were too closely associated with cause and effect to suggest even disappointment, to say nothing of discouragement, but let me refer to an admirable and fine distinction as evidenced in the decision of Gibbs and Hill, which discounted apparent for real results, and settled that the body of their electrification should be upon a single-phase basis, notwithstanding that the largest terminal upon the same railroad was operated upon a direct-current basis.

I envy, indeed, the result that they should be able to produce for the Pennsylvania Company in the use of straight alternating current upon their lines. Even the record of the New York, Westchester and Boston with its straight alternating equipment, whose log sheet reports will show 125,000 miles per car failure, may be surpassed on the Paoli Division by this coming Pennsylvania electrification. As I forecast this record that should be made, I review in retrospect some of the experiences that have caused it to be possible. Among the number are generator windings that have torn themselves loose from their housings by action of 11,000-volt short circuits upon their grounded phases; sectionalizing oil switches on the line hurling their cover plates 100 feet in the air, due to these same short circuits; the overhead contact line parting company with itself, due to high-speed pantograph shoes impinging themselves against the hard spots at hanger points; locomotives nosing their way along the tracks with broken quill springs and grounded motors; and so we might go on drawing the picture of our difficulties based upon lack of experience, but the future is the brighter picture. None of the railroads, not one, will have to go through this. It is all behind us, and present operating statistics are now the proof that the high-voltage alternating-current electrification, with its attendant higher efficiency, will be as reliable as the direct-current, if not more so, on account of the simplicity of its control.

Governed by the right principles, we have passed from the days in which we desired to make it work into those in which we must make it pay. Accurate distributions of the costs in all

departments of construction in their application to power-house, lines, locomotives, and shops, together with expenses incident to the maintenance and operation of these salient features since the work was first undertaken, have shown a declining curve of unit costs throughout these various details as against the progress of time. Some road had to make the first break into the dark. No one had any advice to give, as no one had any experience upon which to base it. Some of our critics have been inclined to view the New Haven electrification as a great experiment. They are right—it was; but as an experiment it has given a cleaner and more reliable ride for the public, and in the end will not cost the New Haven road a (economic) penny; but its greatest value in my estimation has not been so much this as the more stable position in which it has placed the other roads of this country to consider electrification, a subject to which they will have to address themselves in the near future.

The larger part of the experimentation is over, and, from the data assembled, future results, in the application of electricity in heavy trunk line territory, can be predicated on assembled facts, and not predicted from hypothetical analysis. Critics have had it that the so-called "battle of systems" has delayed the electrification of railroads. As an electrical engineer keenly alive to the desirability of interesting railroads in moving their trains by electricity, I am glad if any insistence on my part upon the matter of "system first" has delayed electrification in this country, and argue that every minute of the delay will be a future asset to the railroads.

When we talk about railroads we generally mean trunk lines, and all trunk lines have essentially common and determining characteristics that make the best system of power distribution for one the best for all. Therefore I count it most fortunate that electrification has been delayed. Over the same standard gauge cars of every description can be hauled. Therefore, why not a standard overhead conductor under which every form of electric motive power can operate?

I recall with interest one of the New York Railroad Club meetings, of which many have been held, typified as their "Electrical Night," at which a committee previously appointed reported its recommendations with regard to the application of alternating or direct current to specific situations. Particular stress in this

report was laid in the advocacy of direct current for large terminals. This appeared to me as a fallacious conclusion, as the record of my remarks for that evening will doubtless disclose. It was clockwork typified in the movements made in these great New York Central and Pennsylvania direct-current terminal electrifications. A credit indeed was due the splendid corps of engineers who in those early days were responsible for the decision and execution of these works; yet conspicuous for their absence on this committee was that same corps of engineers, for to have subscribed to such an electrification policy would have included their concession that the tail of the dog was to wag his body! The committee made it clear that if the electrification was to be confined to terminal limits, then without question that electrification should be undertaken upon a direct-current basis. Immediately following this recommendation alternating current was prescribed as best befitting trunk lines. I well recall the hiatus from which my brain reeled as I listened to the speaker divorce the trunk line from its terminal and draw in perpetuity the picture of the one great electrical evil from which it was desirable to escape; namely, the uncongenial marriage of alternating current to direct current. Fortunately we have learned enough about this matter by experience not to fear the execution of such a policy. As evidence of this fact, one of the simplest proofs is a reference to the wonderful reliability and economy of service to which we are treated in serving the great terminal yards at Oak Point and Harlem River with the straight alternating-current switching locomotive. During the past two years, in which 16 engines of this type have been in operation and in which over 1,000,000 locomotive miles in commercial switching service have been recorded, there has been, as previously advised, just one main motor failure. This, however, is touching upon details of which we will speak later, and I have only mentioned it here in support of the argument that all motive power equipment should, if possible, be designed for operation upon one form of current, this being one of the essential conditions precedent to successful electrification.

At this juncture it is of interest to point to the fact that under the single-phase, high-potential contact wire three types of electric motive power—the single-phase, the three-phase, and the direct-current (through the medium of a rectifier)—can operate; thus

each class of equipment is permitted a supply of power unchanging in form.

The principle of cardinal importance to the writer's mind, and one of the conditions affecting the success of main line electrification, may, therefore, be said to be the establishment of a standard system of power distribution, from the contact wires of which shall be delivered power in standard and unchanging form, and, while all electric locomotives or multiple-unit equipment will primarily receive this power in identical form, it may thereafter be modified or transformed to conform to any type of alternating-current or direct-current equipment, which is in turn prescribed by the local conditions. Such a standardization would provide a single high-voltage contact wire running throughout an entire electrification zone upon which are impressed 11,000 volts of 25-cycle, single-phase electricity.

Such a line could have operating beneath it single-phase equipment of the New York, New Haven and Hartford design, three-phase equipment of the Norfolk and Western design, and, finally (through the medium of the rectifier), direct-current equipment of the New York Central design, all of these equipments having entirely dissimilar torque-speed characteristics prescribed as local conditions demand. I believe that we will all admit that such a standardization offers a wonderful flexibility, but, after all this, flexibility is not the real reason for its acceptance, although we cannot fail to class it as one of the facts that form a part of a correct conclusion. The real reasons are rooted in the field of economy, where the railroad dollar must justify its investment. There is no other distribution and contact system that can touch it in efficiency. Its principles have intertwined themselves with every application of electricity in the variegated field of its usefulness, and in no place is its application more apt than in supplying power for train movement.

Up to this point the writer has possibly levied upon your indulgence in treating his subject upon very general lines, but in so doing there has not been a moment when the specific subject of the paper has not been in mind. The subject itself is such a broad one that in truth it must be said that it has been more difficult to know what not rather than what to say, and what has been said has only been in an effort to show that during this pause we have been schooling ourselves by the analysis of the data

secured; sorting it into cost *versus* return; studying comparative results arising under varying conditions; crystallizing out the mistakes that have been made in the past by lack of sufficient experience and information; drawing conclusions that are not guesses on what shall be the future methods to be followed in electrification, and assembling our facts for ready reference and application.

Now, coming to the specific subject of the paper, let me point first to the great underlying condition, apart from the engineering, construction, and operating side, upon which the success of main line electrification, from a combined public and railroad standpoint, is founded: success is entirely dependent upon the *density of traffic.*

A commercially successful electrification may be described as one which, through its agency, cuts the operating expenses of steam-operated territory it has replaced to a figure whereby the savings effected are of an amount sufficient to justify the investment made.

Our experience to date has taught us that electrification points to three principal places where economy of operation can be secured, and in the order of their importance they may be mentioned as follows:

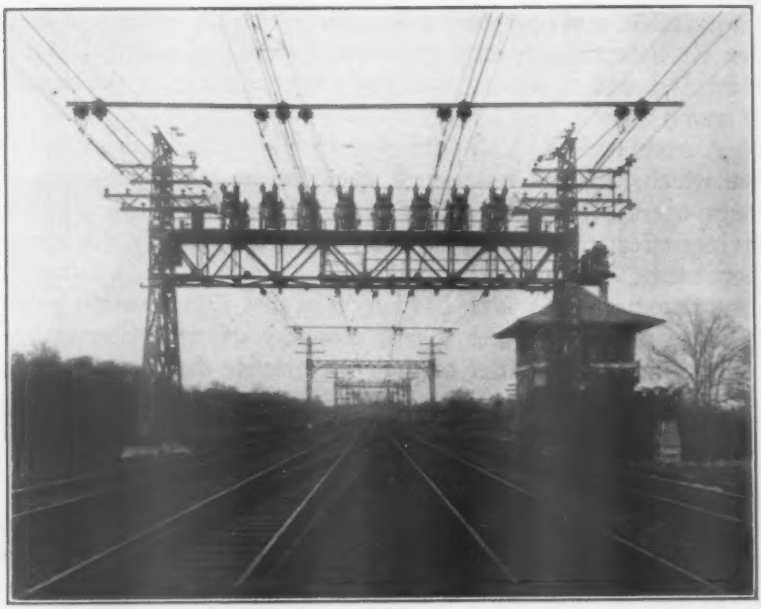
1. Saving in fuel.
2. Saving in motive-power maintenance and repairs.
3. Saving in train miles.

Assets created by electrification, which may at times be controlling factors, as, for example, the reclamation of city terminal property, after the removal of gas and smoke by the elimination of steam locomotives, are of most important consideration. In cases, however, that do not involve large city terminal electrification, the general credits and debits resulting from electrification work may be said to about offset each other, and thus the value of the returns can be based upon the three items first mentioned. If we know the number of freight and passenger train miles in a division proposed for electrification, and the cost of each one of the train miles, to-day we can say with very little chance of error what the cost of each one of those train miles in freight and passenger service will be when that division is operated by electricity. If we were to duplicate the steam train movement by an electric train movement a certain economy would be shown, but by reason

of the ability to concentrate in single train movements greater tractive efforts and higher speeds, greater individual tonnages can be translated, and thus the third item of economy appears in the reduction of train miles.

As bearing on the matter of a reduction in train miles through means of electrification, the three charts applying to studies recently made on the Salt Lake Division of the Denver

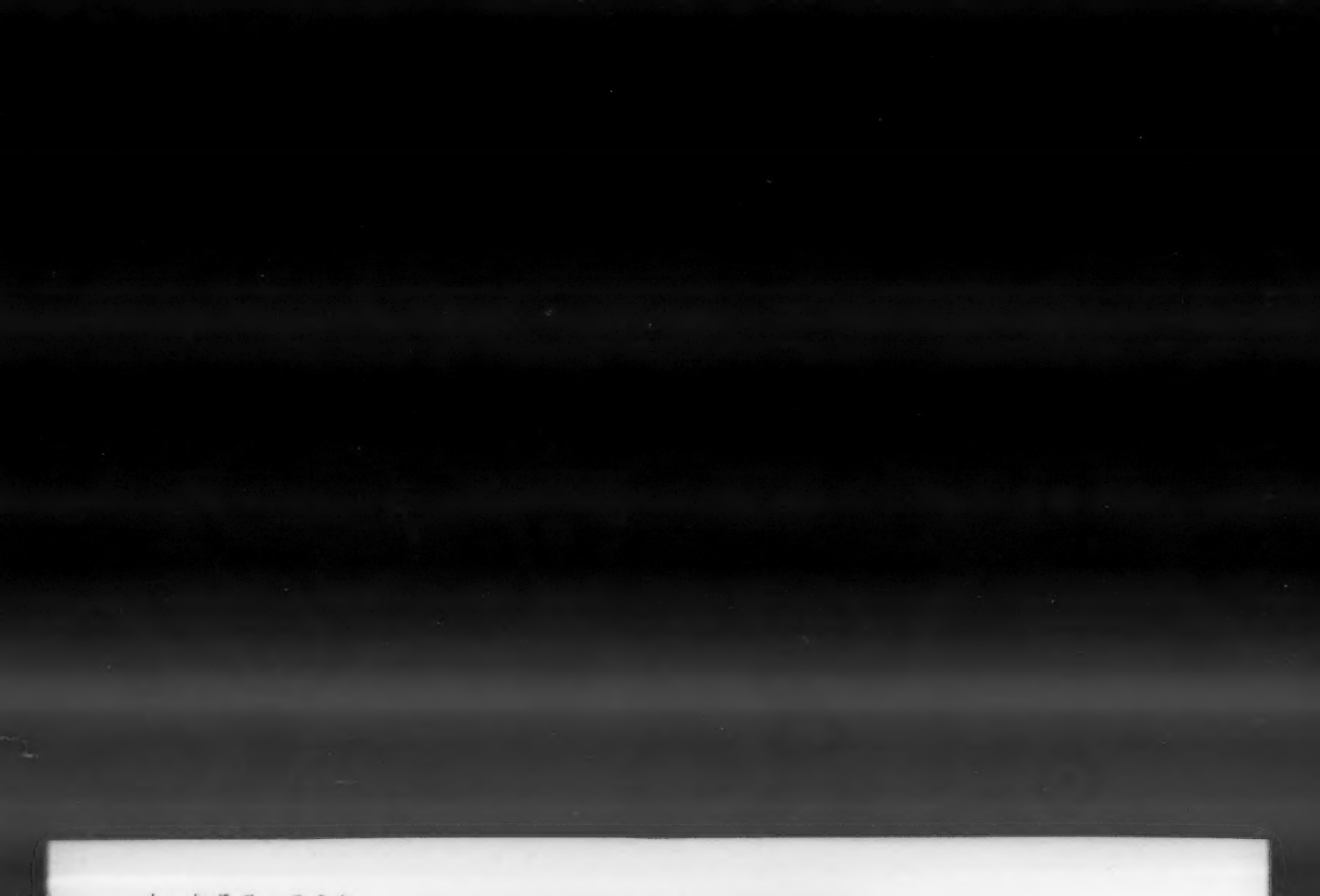
FIG. 1.



Four-track tangent compound catenary construction, showing anchor bridge in the immediate foreground, with sectionalizing switches installed thereon. Signal tower is seen at the right of the tracks, and from this tower sectionalizing switches are controlled. Note also crossover under anchor bridge, with its overhead contact wire.

and Rio Grande Railroad are interesting. In these charts it is of importance to note the great reduction in train movement secured by electrical operation, in combination with the reduction of a section of high grade from 4 per cent. to 2 per cent. for increases of 20 per cent. and 100 per cent. in excess of the former tonnage. The example offered is merely illustrative of this application of economy under conditions of electrification.

Experience with the movement of billions of ton miles in freight, passenger, and switching service by electricity has justi-

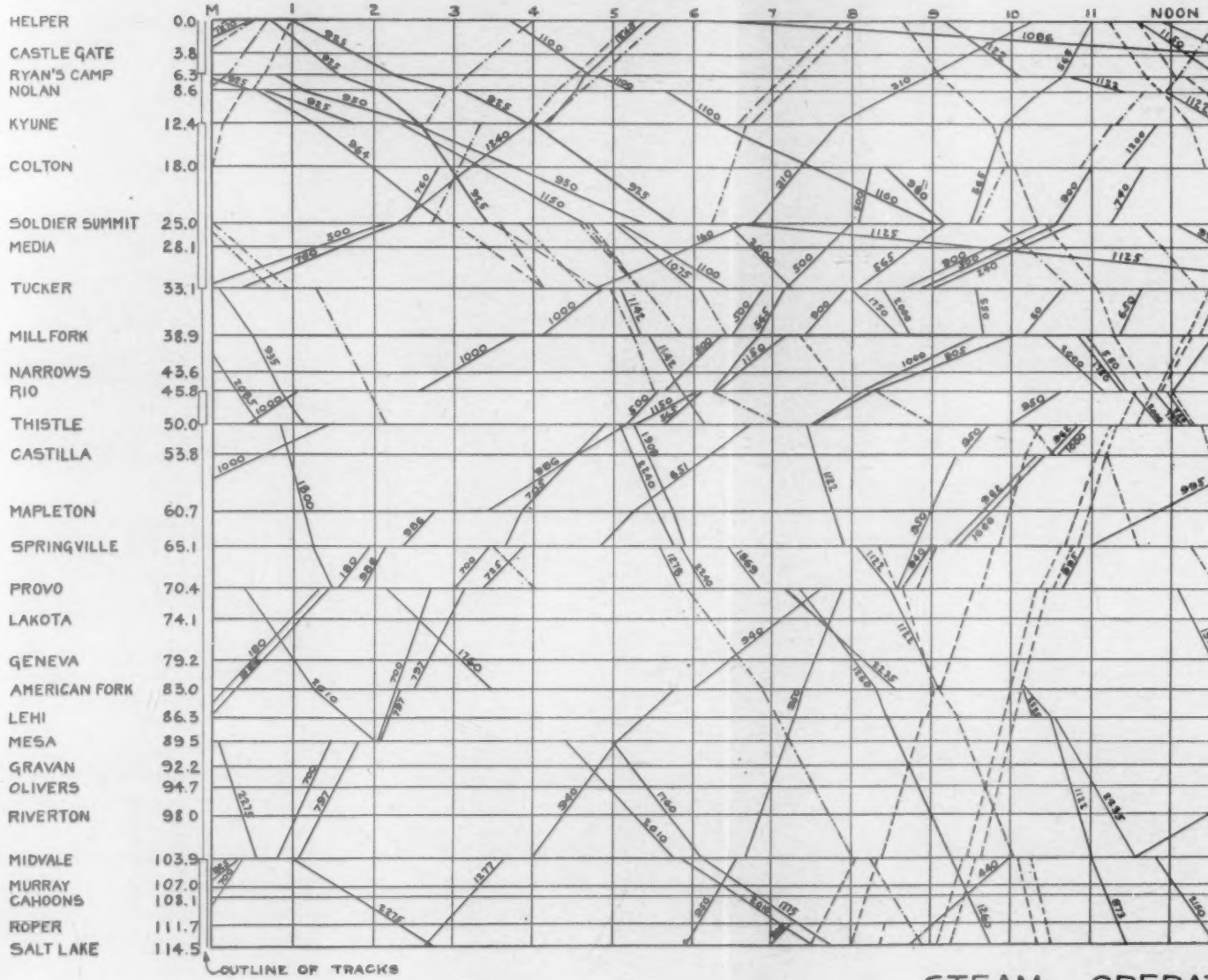


SALT LAKE
TRAIN MOV
OCTOBER 17

-LEGEND

PASSENGER ---- FREIGHT ——— LIGHT ENGINE —·—·—

NUMBERS SHOW TONNAGE HAULED.



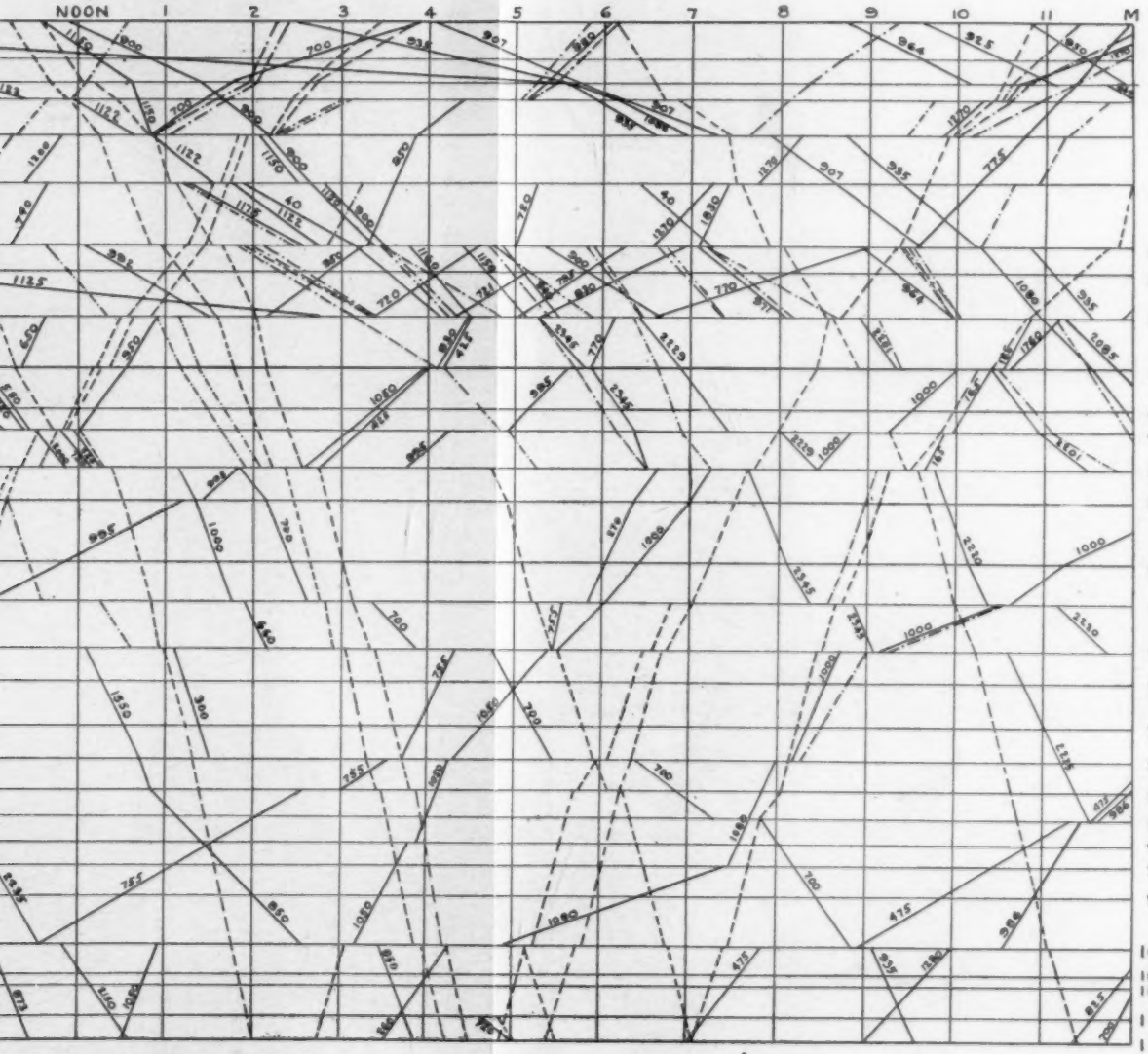
STEAM OPERA

LAKE DIVISION
AIN MOVEMENT

CTOBER 17th 1912

TONNAGE OUT OF HELPER 10767, TONNAGE INTO HELPER 5035.

. . . SALTLAKE 8757, . . . SALTLAKE 12848.



0.0 HELPER
3.8 CASTLE GATE
6.3 RYAN'S CAMP
8.6 NOLAN
12.4 KYUNE
18.0 COLTON
25.0 SOLDIER SUMMIT
28.1 MEDIA
33.1 TUCKER
38.9 MILL FORK
43.6 NARROWS
45.8 RIO
50.0 THISTLE
53.8 CASTILLA
60.7 MAPLETON
65.1 SPRINGVILLE
70.4 PROVO
74.1 LAKOTA
79.2 GENEVA
83.0 AMERICAN FORK
86.3 LEHI
89.5 MESA
92.2 GRAVAN
94.7 OLIVERS
98.0 RIVERTON
103.9 MIDVALE
107.0 MURRAY
108.1 CAHOONS
111.7 ROPER
114.5 SALT LAKE

OPERATION

fied the early predictions that were made in connection with the study of the New Haven electrification; namely, that one pound of coal burned under the boilers of a central electric power station and converted into electrical energy and transmitted to an electric engine will develop twice the drawbar pull at the same speed as a similar pound of coal burned in the firebox of a steam locomotive;

FIG. 2.

Six-track tangent compound catenary construction, showing electric freight locomotive and train. Freight trains are operated between Harlem River and New Haven, the normal maximum tonnage of which may be, with double locomotive and multiple-unit control, up to 3150 tons. The introduction of freight hauled by electricity has permitted the division to increase the steam tonnage rating twice, reduce time by 33 per cent. and train crew expenses to one-half.

and, second, that the maintenance and repairs on electric locomotives of the straight alternating-current type are on the order of one-half of those required for steam locomotives of equal weight on drivers. It is thus seen that the problem of electrification merely revolves around the question of the density of traffic in which the economies aforesaid can be practised, and, therefore, the denser the traffic the greater the requisite motive power for its movement, and hence the greater the saving to be effected. If the schedule of train movement for all roads were

the same, then, based upon the number of tons translated, it would be a simple matter to plot a chart which would show two intersecting curves, one of which represented the savings per annum to be effected by the substitution of electricity for steam, the other the summated cost per annum of interest, depreciation, maintenance, insurance and taxes on the electrical plant, inclusive

FIG. 3.

View in Westchester Yard, Harlem River Branch, showing overhead construction used in electrifying large yards. The cross catenary span in the immediate foreground serves ten tracks. In the case of the Harlem River Yard there are single spans serving eighteen tracks. For equal electrical energy delivered, the cost of this construction is one-third that of the third-rail.

of power-house, lines, locomotives, and shops, necessary to effect these savings, these curves having as common abscissa tons under translation and as ordinates the annual costs respectively represented in the foregoing classes of annual expenditures. The point of intersection of these curves would indicate the density of traffic at which the economic yield of electrification would cover the fixed charges incident to its installation. The curves would also indicate the yield to the railroad that electrification would bring above that of steam operation for traffic densities of greater

d, it
two
per
eam,
tion,
sive

d in
cks.
qual

ect
ler
re-
int
of
er
ld
ld
er

KEY TO FREIGHT TRAIN MOVEMENTS

BETWEEN	WESTWARD				EASTWARD			
	NUMBER OF TRAINS	SPEED M.P.H.	TONS PER TRAIN	NUMBER OF LOCO.	NUMBER OF TRAINS	SPEED M.P.H.	TONS PER TRAIN	NUMBER OF LOCO.
HELPER – KYUNE	8	12.5	2.000	○○ □□	5	20	1.800	□□
KYUNE – SOLDIER SUMMIT	8	23	2.000	□□	5	35	1.800	□□
SOLDIER SUMMIT – DETOUR	5	20	3.000	□□	5	14	1.800	○○ □□
DETOUR – THISTLE	5	20	3.000	□□	5	17	1.800	○○ □□
THISTLE – SALT LAKE	5	35	3.000	□□	5	31	1.800	□□

SALT LAKE

TRAIN MO

CHART "I ; 20% INCREASE IN TONNAGE

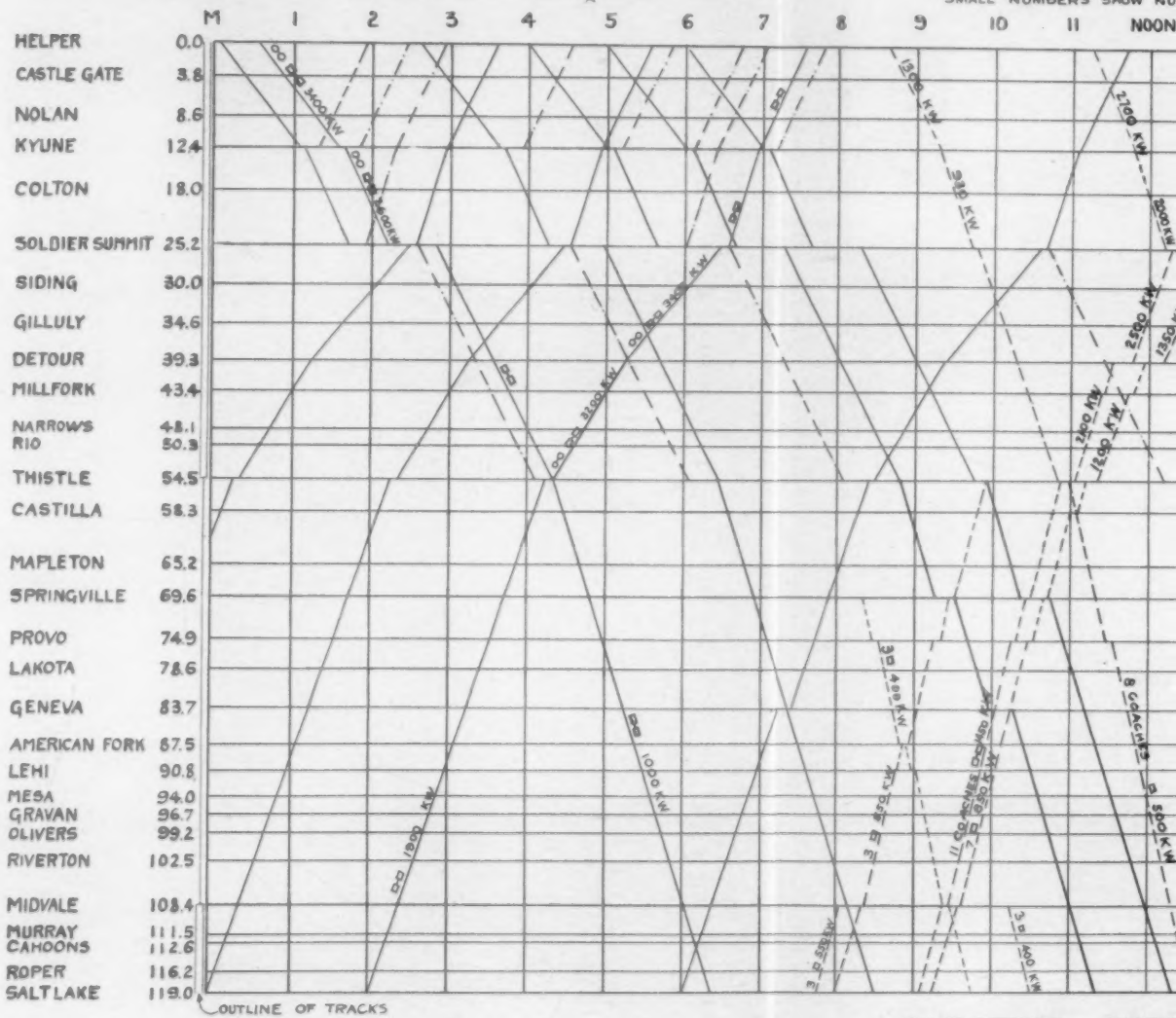
– LEGEN

– – – – – PASSENGER, ——— FRE

○ PUSHER LOCO. , □ CO

○○ & □□ INDICATES TWO LOCO.

SMALL NUMBERS SHOW NU



ELECTRIC OPER

T LAKE DIVISION

RAIN MOVEMENT

E IN TONNAGE OVER CHART OF OCTOBER 17th 1912.

-LEGEND-

———FREIGHT, — — — LIGHT ENGINE

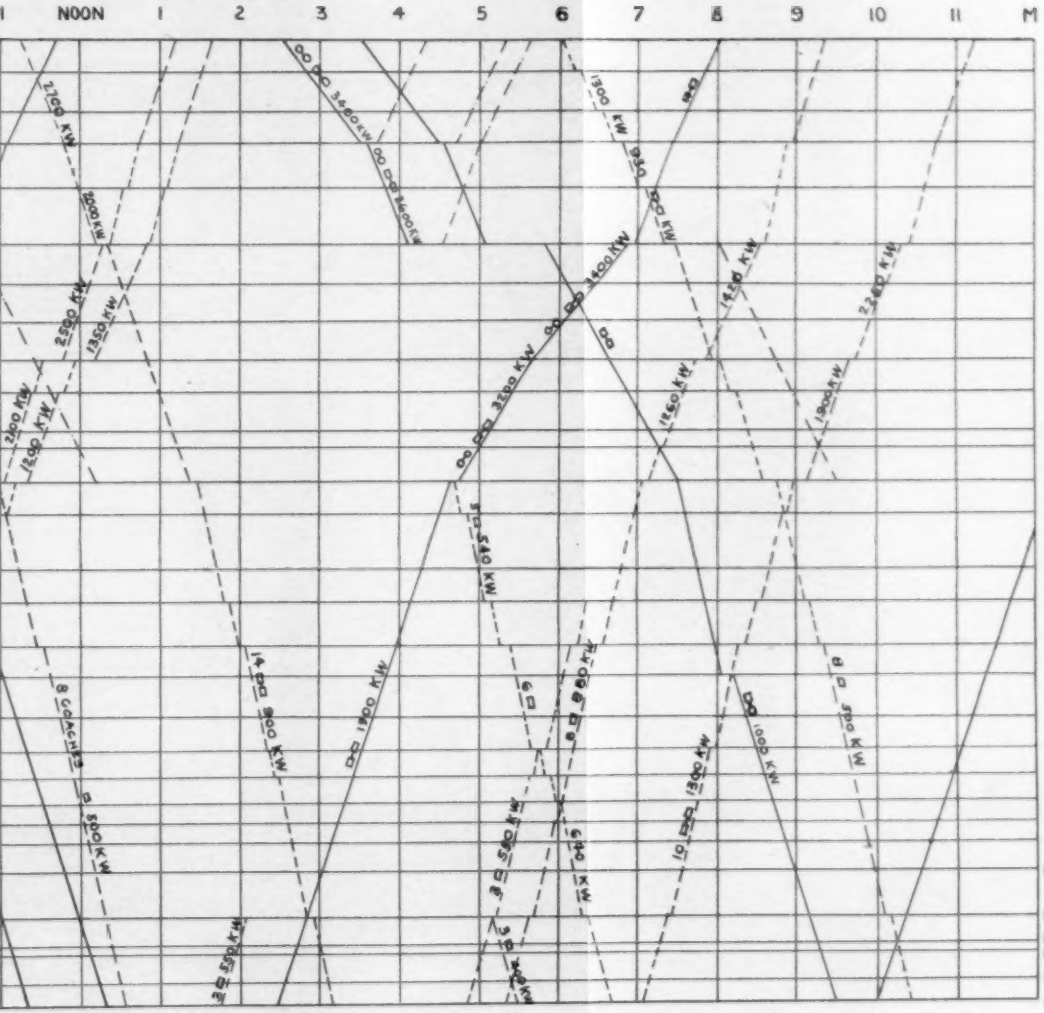
CO. , □ COMBINATION LOCO

TWO LOCO. OPERATED AS ONE UNIT

S SHOW NUMBER OF COACHES.

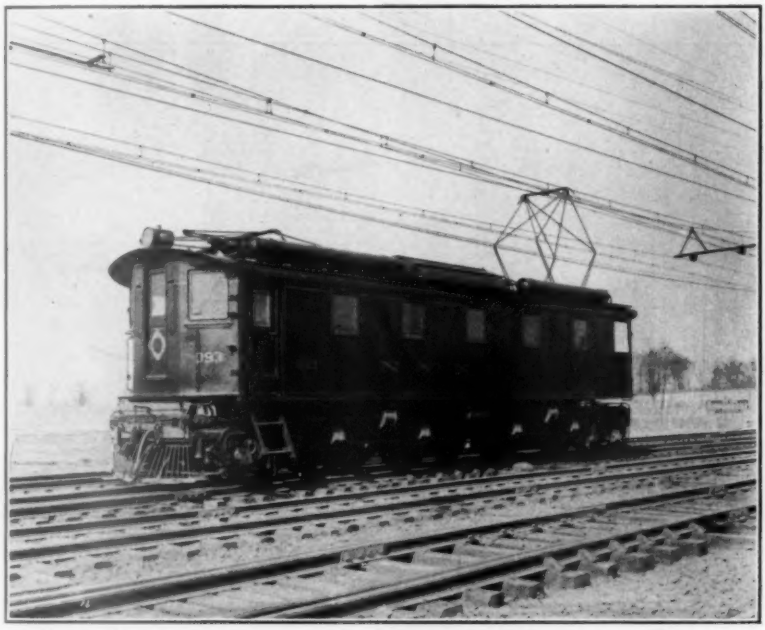
GENERAL DATA

TOTAL TONNAGE WESTWARD HELPER TO SOLDIER SUMMIT	16000 TONS DAILY
SOLDIER SUMMIT TO SALT LAKE	15000 . .
EASTWARD SALT LAKE TO HELPER	9000 . .
NUMBER OF PASSENGER COACHES WESTWARD	30
EASTWARD	36
TRAIN MILES WESTWARD	1217.2
EASTWARD	1141.6


NOON
1
2
3
4
5
6
7
8
9
10
11
M
2700 KW
3000 KW
2000 KW
1350 KW
2400 KW
1800 KW
3600 KW
3600 KW
1900 KW
3400 KW
3500 KW
1350 KW
1650 KW
2300 KW
1900 KW
540 KW
1800 KW
900 KW
1800 KW
900 KW
1800 KW
1000 KW
900 KW
540 KW
540 KW
540 KW
8 COACHES
8 900 KW
8 COACHES
8 900 KW
14 900 KW
8 900 KW
8 COACHES
8 900 KW
8 COACHES
8 900 KW
8 COACHES

amount. The analysis, however, is not as simple as this, for, while a number of roads might translate equal tonnages over equal distances, the local conditions might require a wide variation as to schedule; also such physical adjuncts as grade and cost of electric power supply, labor and material clearly make it necessary to give careful consideration to each individual case. The point which I wish to make, however, is that, with knowledge

FIG. 4.



Standard straight alternating-current freight locomotive capable of handling 1500 tons at 35 miles per hour continuously. Weighs 110 tons, 80 per cent. of which is on drivers; develops a maximum tractive effort of 40,000 pounds, and will maintain a tractive effort of 12,000 pounds continuously. The rated continuous capacity of this electric engine is 1400 horse-power. The overhead contact shoe receives a potential of 10,000 volts, which is transformed to 600 volts and in turn is delivered to the terminals of four twin motor equipments in parallel, each motor on the twin combination receiving a maximum normal potential of 300 volts.

based on experience, operating officials of railroad companies can have an intelligent presentation made to them of the comparative cost relation between steam and electric operation for these several roads. An intimate acquaintance with the ways and methods of the steam railroads of to-day has taught us how the president, the vice-president, the general manager, the general superintendent, the mechanical superintendent, the division superintendent, the

master mechanics, the road foremen of engines, the shop superintendent, and so on down the line to the engineers whose hands are on either the levers of the steam or electric engines, look at operation. Seven years of parallel steam and electric operation on the same division have opened up a world of perspective to the writer, as he has studied the controlling forces which whirl through the beginnings of this conversion from steam to electricity in the trunk line territory of our American railways.

FIG. 5.

Multiple-unit train operating on six-track Harlem River Branch electrification. This multiple-unit train is also designed for operation on the New York Central direct-current third-rail system. Each motor car has sufficient capacity to haul itself and two trailers.

I would count it a serious omission indeed did I not mention the great and able assistance the present general manager of the New Haven Road, Mr. C. L. Bardo, has given in his study of the operating side of this great electrical problem. It is of him that I think when I touch upon one of the essentially real conditions affecting the success of main line electrification, and that is in the matter of administration. Electricity as an agent of power development is as essentially different from steam as the effects which are produced in the application of heat or cold. The steam

locomotive has lived a useful life of eighty years. This is not a prediction that it will not live many more! Even in the clothes of its mechanical ruggedness it is not difficult to conceive of its having once been a pretty delicate machine, deserving of a very great deal of care and attention. The electric locomotive was born of even a more delicate nature, and, while its ruggedness is increasing, it can never possibly be the great mechanical brute that our

FIG. 6.

Electric switcher No. 0213, doing regular switching service in Oak Point Yard. Four of these engines are capable of doing the work of six steam switchers. They weigh 80 tons, with 100 per cent. weight on drivers. They will develop 40,000 pounds tractive effort, and will maintain a tractive effort of 12,000 pounds continuously. Sixteen of these electric engines have recorded over 1,200,000 miles in switching service, and one failure, a burned-out armature, due to a prolonged and excessive load from brakes sticking, is the record of their performance to date.

high-powered steam locomotives may be typified as being to-day. In the same breath, however, it may be said that the steam locomotive can never reach into the zones of usefulness to which the electric engine can at the present day enter.

It is perfectly possible to keep the maintenance and repairs of the electric locomotive down to one-half of those of steam under the most favorable conditions of steam maintenance, and in many cases below this figure. On the other hand, due to the

KEY TO FREIGHT TRAIN MOVEMENTS

BETWEEN	WEST WARD				EAST WARD			
	NUMBER OF TRAINS	SPEED M.P.H.	TONS PER TRAIN	NUMBER OF LOCO.	NUMBER OF TRAINS	SPEED M.P.H.	TONS PER TRAIN	NUMBER OF LOCO.
HELPER - KYUNE	15	12.5	2.000	○○□□	10	20	1.800	□□
KYUNE - SOLDIER SUMMIT	15	23.0	2.000	□□	10	35	1.800	□□
SOLDIER SUMMIT - DETOUR	10	20.0	3.000	□□	10	14	1.800	○○□□
DETOUR - THISTLE	10	20.0	3.000	□□	10	17	1.800	○○□□
THISTLE - SALTLAKE	10	35.0	3.000	□□	10	31	1.800	□□

SALT LAKE DIVISIO

TRAIN MOVEMENT

CHART 2; 100% INCRESE IN TONNAGE O

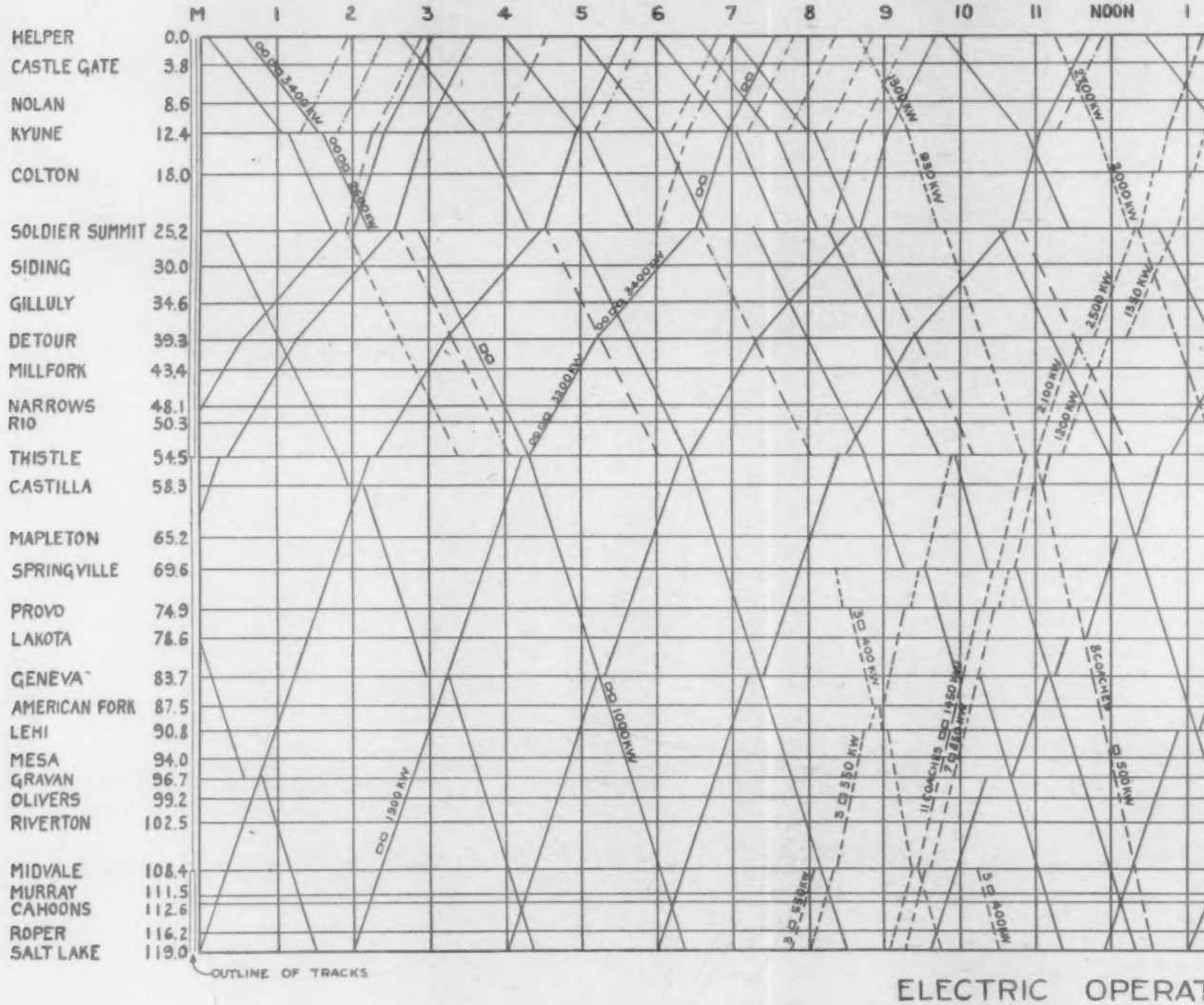
-LEGEND-

PASSENGER ——— FREIGHT

○ PUSHER LOCO., □ COMBINATION

○○ & □□ INDICATES TWO LOCO. OPERATED

SMALL NUMBERS SHOW NUMBER OF



ELECTRIC OPERAT

DIVISION

VEMENT

TONNAGE OVER CHART *1

O—

EIGHT ——·—·—· LIGHT ENGINE

IBINATION LOCO.

O. OPERATED AS ONE UNIT.

MBER OF COACHES.

GENERAL DATA

TOTAL TONNAGE WESTWARD HELPER TO SALT LAKE 30.000 TONS DAILY

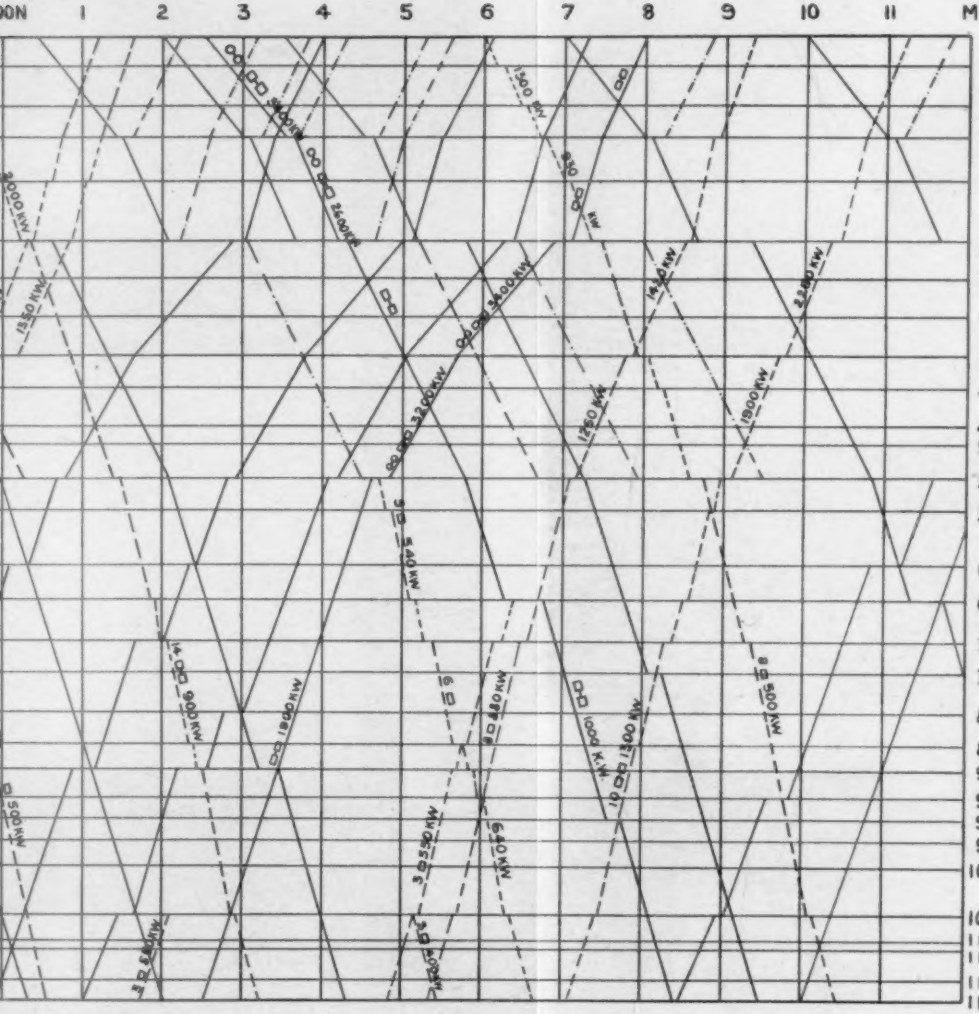
" " EASTWARD SALT LAKE TO HELPER 18.000 " "

" NUMBER OF PASSENGER COACHES WESTWARD 30

" " " " " EASTWARD 36

" " " TRAIN MILES WESTWARD 1862.6

" " " " " EASTWARD 1736.6



PERATION

peculiar nature of the electric engine, which has not as yet been enough appreciated, it will be only by the most rigorous and careful inspection and conformity to rules of operation that this relation can be maintained. Indeed, if electric engines be treated as has been the custom of treating steam locomotives, then their repairs, instead of costing far less, will cost far more than those of the steam engine. The essential difference between the steam and the electric engine is that the former, after it has done all the work it is capable of doing, will lie down, simply stop going, and do this at no cost to its mechanical parts, while an electric engine, like an overwilling horse, if permitted, will work itself to destruction. The commercial life and efficiency of a steam engine may be said to depend on keeping the heat within its cylinder walls, while the commercial life and efficiency of the electric locomotive are based on how cool you can keep its conductors. In the vernacular of the American youth, some difference! Yet, if you ask the old steam superintendent operating the new electric division if he agreed to that distinction, the chances are he would say: "Sure, the conductors should never get hot, especially with a passenger." Mr. Bardo has recognized this great difference between steam and electric operation, and in handling the schedule of electric trains he has emphasized the importance of keeping the train loads down to a point within the safe temperatures of the electric motors performing the schedule. The days are passing when with pride the steam operating man points to the electric locomotive as having been able to perform twice the duty for which it was designed, and the next day wondering why the darned old "electric" blew up on half the load. The point to be established, therefore, is that successful electrification requires that there be in the administrative forces minds trained to the necessity of a different viewpoint from that which has come down through these eighty years of steam service. The magnificent organization that has shaped itself throughout these many years and has standardized itself, one might say, in its application to all roads, need not in any way have its fabrics torn or changed by the introduction of electricity as a motive power, but there must be established in the administrative forces different minds from those in the past to handle these different things of the future. The future must see well-developed electrical cells in the minds of the vice-presidents, general managers, general superintendents, etc., down the line.

An inheritance by the New Haven of the old steam locomotive engineers for the operation of their electric engines is another case where the tail of the dog wags the body. While it is a good argument that these men understand the roadbed and signals better than any one else, this argument fails when engineers without electrical experience or training can bid in the electric runs, depending upon their seniority and record of service. The condition might be alleviated by one set of men, once in remaining in, but there is a constant change, and it is a long time before the steam locomotive engineer divorces himself from the fact that he is not operating a steam locomotive. During his period of learning how to operate the electric engine he does not suffer, the people do not suffer, but the road suffers, and the locomotive suffers most. Here, therefore, we see the necessity of electrically trained men. The very logic of this stand will ultimately require that these things be so, and one of the successes of which we write in this paper is based upon it being made so.

While all of the main line tracks of the New York Division are electrified, there still remains in passenger and freight service, as previously shown, a considerable amount of steam operation, made necessary by the New Haven Road having had to avoid capital expenditure for power-house and motive power equipment. It can be readily understood that a large reduction in operating expense can be effected when the division is placed upon a 100 per cent. electrical basis. On previous occasions when the writer has been dealing with statistics and information made available by his engineering and operating association with the work he was conscious then, and is now, of the danger, in presenting construction and operating costs, of their possible misinterpretation.

Essentially necessary is a wholesome confidence on the part of railroads undertaking electrification that the result predicted will be attained, and what we are doing on the New Haven to-day electrically from an operating standpoint could not be better epitomized than by the presentation of one of the last monthly operating reports. They follow, and are known as the statistics of electrical operation, and give operating information with reference to:

1. The amount, distribution and cost of electric power generated at Cos Cob Station.

2. Statistics and operating costs of electric passenger service.

3. Statistics and operating costs of electric freight service.
4. Statistics covering line and equipment failures.

These records are included in this paper not as an exhibit of something remarkable, but simply to convey to those interested in the electrification of railways the fact that there is daily coming to us a mass of data having reference to the practice of heavy electric transportation, through the agency of which very accurate conclusions may be drawn.

I would ask those who review these statistics with an analytical eye to bear in mind that they are taken from an electrical plant which, from its inception, has been handicapped both from a construction and operating point of view. As before explained, the underlying principle applying to the New Haven electrification required that its motive power equipment be designed to operate on both alternating- and direct-current power, and that, further, on account of inadequate shop facilities in the past it has been necessary, since securing new shop facilities, to make very heavy repairs throughout the entire electric motive power of the road. I have, therefore, to offer this word of caution in analyzing the statistics that are presented, for it is to be noted that the cost of locomotive repairs is high. For example, referring specifically to the table of operating costs of electric passenger engines (page 552), it is to be noted that in the month of October the repairs are recorded as 8.56 cents per locomotive mile, while for November these repairs have increased to 10.61 cents per locomotive mile. At the first blush this would indicate that the new shop facilities were increasing rather than diminishing maintenance costs. This, however, may be explained by the fact that all of the passenger engines have been undergoing general repairs, and invoices for material were passed in greater amounts for November than for October. Many of the electric locomotives have not received a general overhauling since 1907, and during this time their log sheets of operation show some of the locomotives have made over 350,000 miles.

Showing conclusively, however, what can be done with electrical equipment under the care of a better maintenance, I have taken the first ten engines that have received general repairs and present herewith in the following ten tables segregated monthly costs and mileages made since these engines have passed through the shops.

Notwithstanding these engines are of the alternating current-

direct current type, it is of interest to note that their records so far show an average cost of under five cents per locomotive mile. It is of particular interest to note that locomotive No. 032, which received its overhaul first, has now operated 93,140 miles at an average cost of 3.6 cents per locomotive mile.

These maintenance figures for the ten engines give a sharp contrast to those in the general table of passenger engine operating costs (p. 552) and emphasize the lack of maintenance to which the electric locomotives were subjected in the early days of their operation. Had conditions permitted our electric passenger engines to be of the straight alternating-current design, in my opinion their average maintenance would not have exceeded 4 cents per locomotive mile.

During the past six years of electric operation there have been collected some very valuable data with regard to the amount of power required to operate trains of variable tonnage in passenger, freight, and switching service. Based upon this data, the power required to operate trains under normal or peak conditions of schedule can be calculated with results practically coinciding with the estimates.

By means of wattmeters installed on all locomotives and motor cars it has been possible to record the differences of power required by trains operating under local and express conditions. The long period over which these statistics were kept and power rate constants thus developed has permitted us to abandon an elaborate tabulation and consolidate the information in the more general statement (pp. 547 and 548). Of value to those who are interested to follow more closely these results, Tables 11, 12, and 13 will be of assistance. These tables are compiled from the June, 1914, statistics of electric passenger and freight train operation between Woodlawn and points east to New Haven. At that time the overhead system had only recently been completed to New Haven, and there was but a small percentage of electric service, both as regards passenger and freight, between Woodlawn and New Haven, and, while the tonnage in both passenger and freight service has been greatly increased since that time, these tables, however, may be taken as giving reliable data in connection with the electric train movements recorded. The watt hours per ton mile (abbreviated in tables as W.H.P.T.M.) are secured through meters recording input power to the electric motors. To determine the actual amount of power taken from

the contact wire, these figures should be divided by 97 per cent., thus allowing an average loss of 3 per cent. for the step-down transformers installed on the electric engines and motive power. As examples of the increments of electric service, since the extension of the electrification to New Haven, while it is to be noted that the total electric passenger ton miles for June, 1914, were approximately 41,000,000 and that of the freight 9,400,000, the former has now increased to 62,000,000 and the latter to 44,000,000.

Of especial interest to the writer with regard to the tables covering electric passenger operation is the variation in watt hours per ton mile for the various express and local services. For example, it is to be noted that the power rate for New Haven express trains eastbound is 31.4 watt hours per ton mile, this rate being increased slightly for trains operating to Stamford; the rate rises quite rapidly for trains operating in local service to Stamford, and continues to rise for local trains operating to Port Chester and New Rochelle respectively. It is, of course, well known that the rate of power supply per ton for express operation is very much lower than that required for local operation, as in the case of the latter the train suffers, under the conditions of braking, the loss of the kinetic energy stored in it under the conditions of acceleration. The increasing watt hours per ton mile as shown in the tables are practically proportional to the diminishing distance between train stops. It may also be said that the distance between stops increases progressively east of New York City, and if, for example, suburban territory under consideration for electrification has to be served by train schedule with distances between stations approximately the same as those obtaining on the New Haven Road, the " power rate " constants as shown in these tables will be found to be sufficiently accurate in the study of power necessary to train movement.

In the tabulated statistics covering electric freight operation the point of principal interest is the difference between the rate per ton mile as indicated in the June tabulation as against those shown under the general tabulation of freight service (pp. 554 and 555), where it is to be noted that the kilowatt hours for fast and slow freight are, on the average, considerably below 30 watt hours per ton mile, this rate being based upon the tonnage of the trailing load. Allowing for the weight of the electric engine, the watt hours per ton mile will be reduced to 26, and, as some 200,000,000

ton miles have been actually recorded by meter registration in freight service, it may be said that 30 watt hours per ton mile on level track is a reliable figure, with slight margin to cover electric freight operation in a combination of fast and slow service; *i.e.*, without stops for trains averaging between 1500 and 3000 tons trailing load.

It is of interest at this juncture to point to an interesting experience we have had in connection with the electrical operation of heavy freight trains. It was first thought that when these large train units were placed on the line the power-house would be subjected to very heavy drafts of power under conditions of accelerating them. The reverse, however, was found to be the case, and where, previous to the operation of these trains, the power station output curve showed peaks of a fluctuating character, these heavy trains have served to smooth out the curve of power station output. A reasonable explanation of this would seem to rest in the fact that when a number of the heavy trains are under translation, and it becomes necessary to accelerate one from rest, the supply of current necessary to this acceleration, while not reducing the line voltage materially, does so, however, to a point which corresponds to a speed of the trains in translation lower than the speed at which they are actually operating, and thus these heavy trains, by their own mass energy, as in the case of a flywheel, automatically release a large amount of power, which becomes available for the accelerating train.

In the foregoing pages I have confined myself to the presentation of operating data, from which I believe very accurate conclusions can be drawn, having regard to the costs incident to electric operation, the only expenses that are materially changed in the conduct of railway transportation being, as previously stated, in the matter of fuel, engine repairs, and train miles. With definite information developed as to these items, it is not a difficult matter for those experienced with their application to interpolate them into the steam operating accounts in the study of railroads considering electrification. I have thought, therefore, that the broader manner of handling this subject would be not to show concrete cases where the conditions were such as to insure the success of electrification, but rather present the constants of economy that were generally applicable, at least very approximately so, to all railway situations, granting, of course, that each individual study would have its qualifying factors which

local conditions would control; as, for example, it is quite possible for a complete electrification to turn upon the cost of coal. The greater the cost of coal the stronger is the argument for electrification from the fuel aspect. For example, if two railroads, one burning $2.50 coal and the other burning $5 coal, should electrify, and in each case reduce their coal consumption by 100,000 tons per year, they would respectively save $250,000 and $500,000 per annum. In the case of the railroad burning the $2.50 coal this saving would, at 5 per cent., represent capitalized values amounting to $5,000,000, while in the case of the railroad burning the $5 coal the capitalized values would be $10,000,000. In both cases the capitalized values should be credited against the construction account for electrification.

The matter of savings to be effected in engine repairs is likewise subject to local conditions, for, while it may be said that steam locomotive repairs, upon an average, may be placed at 10 cents per locomotive mile, on the other hand there may be situations where the railroad has, for example, to use water of severe scaling characteristics and thus run up the cost of repairs excessively.

In the matter of train miles the savings to be effected are dependent upon local conditions, but it can be stated as a general conclusion, based on a very considerable experience, that:

1. Electric engines on the order of 100 tons on drivers should be maintained at a rate not exceeding 5 cents per locomotive mile.

2. The coal bill for transportation is cut to at least one-half.

Having determined for any situation what savings can be effected by the substitution of electricity for steam, then, as previously stated, the commercial justification of a change to the new motive power is entirely based upon whether these savings will cover the interest, insurance, depreciation, and taxes on the electrical investment necessary.

In past papers I have refrained from presenting construction costs to show what investment is necessary to operate trunk line territory by electricity, and I believe that this policy will be accepted as having been justified in advising that an analysis of the distribution account of our latest line construction (between Stamford and New Haven) shows its unit costs (four-track) to have been one-half of that incurred in the original work, and.

while further economies will, of course, follow, I feel that the curve of decreasing electrical investment for electrification has flattened at least enough to present Tables 14, 15, and 16, which follow, indicating the costs incident to six-track, four-track, two-track, compound and single catenary for curves and tangent construction as a guide to what can be done. To those considering these figures I would offer a word of suggestion that the overhead system of the New Haven Road was designed to coördinate with a roadbed which is the throat of the entire eastern New England traffic. Very high safety factors have been included in it, both as regards wire and steel, and it has been many times, particularly during the last season, subjected to high wind velocities, the effects of which have been augmented by ice formation, increasing its projected area.

A general factor of safety of three is prevalent throughout the whole construction, whether on the 200-foot river transmission towers with 800-foot spans or on the regular catenary construction, in each instance based on ice coatings of ½ inch all around, with wind velocity of 60 miles an hour. I might add, also, that we have been fortunate enough not to have lost a wire due to the above causes throughout the history of the electrification.

Briefly referring to the tables of construction costs, it is to be noted that the supporting steel bridges have a normal spacing of 300 feet, the trusses of which are designed to withstand the breakage of any of the main supporting messenger wires, and permit also the support at any point of four signals of 2000 pounds in weight each.

As local conditions make different requirements for sectionalization, construction costs are given for continuous catenary construction for tangent and curved track, and, to facilitate the introduction of sectionalizing costs, individual figures for anchor bridge and control sectionalization are given under tables showing costs varying for the different number of tracks under consideration.

Electrification, like everything else, under effects of standardization gets down to a pound or foot basis; the costs tabulated for the different types of construction, sectionalization and control may be combined to determine total estimates on work conforming to the requirements of the local conditions.

With regard to electric motive power equipment, papers that have preceded this one have discussed in detail physical dimension,

weight, and operating characteristics of electric passenger, freight, and switching engines and multiple-unit motor cars. The motive power feature of electrification, like its other parts, has virtually reached the pound stage. Electric locomotives of approximately 100 tons will, under present conditions of cost of labor and material, vary between 18 cents and 20 cents per pound. This figure is practically irrespective of speed-torque characteristics, a high-speed passenger locomotive and a low-speed switcher not varying greatly in cost upon a pound basis. Multiple-unit cars, now usually built of steel, do not vary greatly from the above figures, but, if anything, may be quoted as being slightly higher in cost per pound.

The determining characteristics of the locomotives to be purchased in an electrification will, of course, entirely depend upon the local conditions which control the maximum and continuous tractive efforts in passenger and freight service, they in turn depending upon the weight of trains and length of grades, capacity of equipment depending likewise on the two foregoing factors and schedule requirements.

The above approximate quotations on engine costs are presented merely to give a general idea of this department of expense in connection with electrification. As a concrete example in application of the above general statements, I would say that a first-class, high-speed, 100-ton, straight alternating-current electric passenger locomotive, capable of handling a 250-ton trailing load in normal large city suburban service, should cost $40,000. A steam locomotive which would do the same work would probably not cost more than $15,000, but the savings effected due to the greater operating economy of the electric engine would represent a figure of twice or three times the amount invested in the electric engine. Thus we might say that for every electric engine we purchase we would be justified at least in making a capital investment of $40,000 to cover the cost of electric power-houses and transmission equipment necessary to supply that electric engine with current. By this reasoning we again approach the answer as to the conditions affecting the success of main line electrification in the fact that it is the density of traffic and in the use of a large number of electric engines by which we can save enough money to pay for the capital expenditure necessary to the supply of power to them for the operation of many trains.

Of late many interesting and valuable papers on electrification have been written, wherein the authors have presented comparable data as between steam and electric operation on specific territory under contemplation.

As mentioned in the earlier pages of the paper, there are many places where electrification would bring a betterment both to the public and to the railroad, but the writer has thought the subject would be better served by a general exposition of his operating and construction experience in connection with a heavy trunk line electrification that has been serving the public for the past eight years, and to draw from it the significant facts and factors from which basic conclusions can be drawn to apply elsewhere.

In concluding the paper I would plead for an especially conservative point of view on the part of the public with regard to electrification. While the savings to be effected under certain conditions of electrification may be considerable, on the other hand the construction investment necessary to these savings may be very great. So many roads in this country have either passed or lowered their dividends, the chief example of which being a part of the great Pennsylvania system, that it is hardly necessary to emphasize the fact that only a healthy condition of finance throughout the country will warrant the consideration of electrification, and again I would say that partial electrification, such as that applying to yards only and not main line, while it might prove of advantage to a public, might at the same time prove to be a serious and unfair burden for the railroad to carry.

The Public Service Commissions are as much the guardians of the railroads as the people they serve, and the many billions in dollars representing the shrinkage in value of railroad securities in the last few years have awakened in the hearts and minds of the public and the commissioners the fact that no further obligations can be imposed upon the railroads, except that they be justified from a fair railroad business standpoint, such equity of treatment describing the duty of the commissioners in whose hands rests the justice of any demand. The electrification of great railroad terminals in particular presents conditions in which the maximum cost is combined with the minimum direct return upon the invested capital, and without some reasonable assurance of adequate return it will be more difficult to secure the necessary capital for such improvements.

TABLE 1.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 032.

	1913					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Labor	32.90	83.01	61.59	23.67	20.18	89.17
Material	20.68	38.61	67.96	21.64	34.56	104.86
Total labor and material	53.58	121.62	129.55	45.31	54.74	194.03
Mileage	4802	5517	4695	4716	4687	4592
Cost per mile	.011	.022	.028	.010	.012	.042
Average cost per mile	.011	.017	.020	.018	.017	.021
Total miles to date	4,802	10,319	15,014	19,730	24,418	29,005

	1914					
	Jan.	Feb.	Mar.	April	May	June
Labor	200.97	85.94	36.52	65.42	91.01	70.70
Material	95.79	27.12	29.15	32.57	70.01	90.28
Total labor and material	296.76	113.06	65.67	97.99	161.02	160.98
Mileage	4,392	6,017	5,310	5,270	5,889	5,839
Cost per mile	.068	.019	.012	.019	.027	.028
Average cost per mile	.027	.026	.024	.024	.024	.024
Total miles to date	33,397	39,414	44,724	49,995	55,884	61,723

	1914					
	July	Aug.	Sept.	Oct.	Nov.	Dec.
Labor	212.36	74.45	147.53	219.47	55.25	.....
Material	131.49	156.72	173.96	780.92	146.09*	.....
Total labor and material	343.85	231.17	321.49	1000.39	90.84*	.....
Mileage	6,165	7,401	5,459	5,678	6,714	.....
Cost per mile	.056	.031	.058	.176	0	.....
Average cost per mile	.027	.027	.030	.039	.036	.....
Total miles to date	67,888	75,289	80,748	86,426	93,140	.....

NOTE.—Cost in dollars. * Cr.

TABLE 2.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 041.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	17.15	72.04	169.91	113.51	105.56	195.78
Material	8.92	78.24	362.15	288.68	32.29*	473.13
Total labor and material	26.07	150.28	532.06	402.19	73.27	668.91
Mileage	2,912	7,974	8,031	5,990	6,096	5,965
Cost per mile	.009	.018	.066	.067	.012	.112
Average cost per mile	.009	.016	.037	.044	.038	.050
Total miles to date	2,912	10,886	18,917	24,907	31,003	36,968

NOTE.—Cost in dollars. * Cr.

TABLE 3.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 037.

	1914							
	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	35.93	61.68	72.78	93.79	119.65	107.20	75.63	115.50
Material	4.69	35.94	159.83	102.73	212.87	184.26	209.81*	47.34
Total labor and material	40.62	97.62	232.61	196.52	332.52	291.46	134.18*	162.84
Mileage	538	4,020	5,641	7,643	8,341	7,203	7,217	6,367
Cost per mile	.075	.024	.041	.026	.040	.040	0	.026
Average cost per mile	.075	.030	.036	.032	.034	.036	.026	.026
Total miles to date	538	4,558	10,199	17,842	26,183	33,386	40,603	46,970

NOTE.—Cost in dollars. *Cr.

TABLE 4.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 028.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	2.04	63.12	135.80	119.00	259.41	78.35
Material	17.25	25.15	211.95	221.73	159.11	39.25
Total labor and material	19.29	88.27	347.75	340.73	418.52	117.60
Mileage	2,103	3,902	6,788	5,398	6,526	8,256
Cost per mile	.009	.023	.051	.063	.064	.014
Average cost per mile	.009	.018	.036	.044	.049	.040
Total miles to date	2,103	6,006	12,794	18,192	24,718	32,974

NOTE.—Cost in dollars.

TABLE 5.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 020.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	50.54	148.29	129.71	120.20	127.45	76.35
Material	29.84	30.19	64.29*	195.31	55.41	248.09
Total labor and material	80.38	178.48	65.42	315.51	182.86	324.44
Mileage	5,391	7,997	8,175	7,227	6,664	6,348
Cost per mile	.015	.022	.008	.043	.027	.051
Average cost per mile	.015	.019	.015	.022	.023	.027
Total miles to date	5,391	13,388	21,563	28,790	35,454	41,802

NOTE.—Cost in dollars. *Cr.

TABLE 6.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 016.

	(1913)	1914				
	Dec.	Jan.	Feb.	March	April	May
Labor	23.52	71.03	108.88	78.80	132.74	106.13
Material	52.16	46.61	55.88	29.91	77.26	51.72
Total labor and material	75.68	117.64	164.76	108.71	210.00	157.85
Mileage	3,260	4,820.5	5,300	5,139.5	4,868	4,222
Cost per mile	.023	.024	.031	.021	.043	.037
Average cost per mile	.023	.024	.027	.025	.029	.030
Total miles to date	3,260	8,080.5	13,380.5	18,520	23,388	27,610

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	155.66	93.52	112.85	129.38	108.75	221.59
Material	179.80	91.61	152.97	21.28	64.64	13.86*
Total labor and material	335.46	185.13	265.82	150.66	173.39	207.73
Mileage	4,347.5	8,282	8,386	5,644	8,096	5,236
Cost per mile	.077	.022	.032	.027	.021	.040
Average cost per mile	.037	.033	.033	.033	.031	.032
Total miles to date	31,957.5	40,239.5	48,625.5	54,269.5	62,365.5	67,601.5

NOTE.—Cost in dollars. * Cr.

TABLE 7.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 01.

	1914					
	June	July	Aug.	Sept.	Oct.	Nov.
Labor	0	96.38	156.60	175.30	133.64	81.76
Material	0	285.76	351.57	312.04	84.85	15.03*
Total labor and material	0	382.14	508.17	487.34	218.49	66.73
Mileage	571	7,183	7,396	6,006	5,812	6,842
Cost per mile	0	.053	.069	.081	.038	.010
Average cost per mile	0	.049	.059	.065	.059	.049
Total miles to date	571	7,754	15,150	21,156	26,968	33,810

NOTE.—Cost in dollars. * Cr.

TABLE 8.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 019.

	1914				
	July	August	Sept.	Oct.	Nov.
Labor	22.07	121.75	84.22	145.20	110.45
Material	4.18	406.70	207.84	129.73	317.68
Total labor and material	26.25	528.45	292.06	274.93	428.13
Mileage	2,886	7,894	7,766	6,938	5,056
Cost per mile	.009	.067	.039	.040	.084
Average cost per mile	.009	.051	.046	.044	.051
Total miles to date	2,886	10,780	18,546	25,484	30,540

NOTE.—Cost in dollars.

TABLE 9.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 05.

	1914						
	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	29.82	109.64	43.55	117.45	113.10	235.34	88.80
Material	83.60	71.29	30.86	309.76	148.05	322.91	129.96
Total labor and material	113.42	180.93	74.41	427.21	261.15	558.25	218.76
Mileage	2,268	5,432	7,937	8,566	5,497	6,783	6,578
Cost per mile	.05	.033	.009	.050	.047	.082	.033
Average cost per mile	.05	.038	.024	.032	.036	.044	.043
Total miles to date	2,268	7,705	15,637	24,203	29,700	36,483	43,061

NOTE.—Cost in dollars.

TABLE 10.

PERFORMANCE OF N. Y., N. H. AND H. R. R. ELECTRIC PASSENGER LOCOMOTIVE 011.

	1914						
	May	June	July	Aug.	Sept.	Oct.	Nov.
Labor	34.55	43.59	145.87	114.21	211.08	74.86	166.71
Material	61.61	18.69	85.08	230.08	316.83	128.33	70.75
Total labor and material	96.16	62.28	230.95	344.29	527.91	203.19	237.46
Mileage	1,017	5,671	6,243	6,837	6,078	8,122	5,690
Cost per mile	.094	.011	.037	.050	.087	.025	.042
Average cost per mile	.094	.023	.030	.037	.049	.043	.042
Total miles to date	1,017	6,688	12,931	19,768	25,846	33,968	39,658

NOTE.—Cost in dollars.

TABLE 11.

STATISTICS COVERING ELECTRIC PASSENGER MOVEMENT AND "POWER RATE" CONSTANTS FOR DIFFERENT SERVICES—EASTBOUND.

	New Haven express trains	Stamford express	Stamford local	Port Chester trains	New Rochelle trains	Total
Number of trains	52	901	667	185	2	1807
Number of locomotives	84	1407	859	214	2	2566
Number of cars	497	7,054	3,875	1,000	10	12,436
Tonnage	35,625	566,033	279,904	67,884	619	950,065
Train miles	3,120	18,921	14,003	2,405	8	38,457
Locomotive miles	5,048	30,954	18,894	2,889	8	57,793
Car miles	29,304	148,134	80,263	13,000	40	270,741
Ton miles	2,108,700	11,886,253	5,832,923	882,492	2,456	20,712,824
K. W. H. used	66,076	405,835	343,846	58,933	222	874,912
W. H. Pr. T. M.	31.4	34.2	59.0	66.7	90.2	42.2

Stamford local trains include one train, New Rochelle to Stamford.

TABLE 12.

STATISTICS COVERING ELECTRIC PASSENGER MOVEMENT AND "POWER RATE" CONSTANTS FOR DIFFERENT SERVICES—WESTBOUND.

	New Haven express trains	Stamford express	Stamford local	Port Chester trains	New Rochelle trains	Total
Number of trains	49	958	604	185	0	1,796
Number of locomotives	78	1,502	791	185	.....	2,556
Number of cars	434	6994	3941	972	.....	12,341
Tonnage	31,963	574,569	261,202	62,559	.....	930,293
Train miles	2,940	20,118	12,684	2405.	.....	38,147
Locomotive miles	4,620.5	33,044	17,402	2,497.5	.....	57,564
Car miles	24,855.5	146,870	81,676	12,591	.....	265,992.5
Ton miles	1,899,957	12,065,689	5,441,943	811,539	.....	20,219,128
K. W. H. used	60,900	486,203	346,935	62,734	.....	956,772
W. H. Pr. T. M.	32.0	40.3	63.7	77.3	.....	47.4

TABLE 13.

STATISTICS COVERING ELECTRIC FREIGHT MOVEMENT AND "POWER RATE" CONSTANTS FOR EASTBOUND AND WESTBOUND SERVICE.

	Eastbound	Westbound	Total
Number of trains	109	116	225
Number of locomotives	109	117	226
Number of cars	2,939	2,829	5,768
Tonnage	106,905	86,706	193,611
Train miles	5,273	5,564	10,837
Locomotive miles	5,486	5,784	11,270
Car miles	142,542	135,792	278,334
Ton miles	5,184,893	4,161,888	9,346,781
K. W. H. used	170,259	137,048	307,307
W. H. Pr. T. M.	32.8	33.0	32.9

TABLE 14.

COST FOR CATENARY CONSTRUCTION.

6-track compound catenary	Tangent 300′ span	Curve 0°-1′ to 1°-0′ 300′ span	Curve 1°-1′ to 2°-0′ 300′ span	Curve 2°-1′ to 3°-0′ 300′ span	Curve 3°-1′ to 4°-0 260′ span with pull-off
Steel	$14,390	$17,810	$19,600	$23,480	$27,500
Concrete	4,920	5,640	6,330	7,600	10,600
Catenary material	16,650	16,650	16,650	16,650	17,910
Catenary labor	2,800	2,900	2,900	2,900	3,220
Total	$38,760	$43,000	$45,480	$50,630	$59,230

4-track compound catenary	Tangent 300′ span	Curve 0°–1′ to 1°–15′ 300′ span	Curve 1°–16′ to 2°–15′ 300′ span	Curve 2°–16′ to 3°–1′ 260′ span	Curve 3°–1′ to 4°–45′ 260′ span with pull-off pole
Steel	$9,350	$11,530	$13,280	$15,800	$18,850
Concrete	3,110	2,890	4,080	4,700	7,640
Catenary material	11,050	11,050	11,050	11,360	12,060
Catenary labor	1,980	2,080	2,080	2,080	2,390
Total	$25,490	$27,550	$30,490	$33,940	$40,940

TABLE 14—*Continued.*

COST FOR CATENARY CONSTRUCTION.

2-track compound catenary	Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–0′ 200′ span	Over 4°–1′ curve 200′ span with pull-off pole
Steel	$6,900	$7,220	$7,830	$9,030	$11,400	$16,160
Concrete	3,580	3,580	4,280	4,910	6,380	10,300
Catenary material	5,580	5,580	5,580	5,680	5,870	6,520
Catenary labor	1,130	1,230	1,230	1,300	1,310	1,410
Total	$17,190	$17,610	$18,920	20,920	$24,960	$34,450

2-track single catenary	Tangent and curves up to 2°–30′ 300′ span	Curve 2°–31′ to 3°–31′ 260′ span	Curve 3°–31′ to 4°–30′ 200′ span	Curves above 4°–30′ with pull-off pole 200′ span
Steel	$6,680	$7,700	$10,500	$14,900
Concrete	3,000	3,300	4,600	9,000
Catenary material	3,530	3,600	3,760	4,300
Catenary labor	510	510	525	650
Total	$13,720	$15,110	$19,385	$28,850

TABLE 15.

COST FOR CATENARY CONSTRUCTION.

Cost for One Mile Single Track of a 6-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–0′ 300 span	Curve 2°–1′ to 3°–0′ 300′ span	Curve 3°–1′ to 4°–0′ 260′ span with pull-off pole
$6,460.00	$7,166.60	$7,580.00	$8,438.60	$9,870.00

Cost for One Mile Single Track of a 4-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–15′ 300′ span	Curve 1°–16′ to 2°–15′ 300′ span	Curve 2°–16′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–45′ 260′ span with pull-off
$6,372.50	$6,887.50	$7,622.50	$8,485.00	$10,235.00

Cost for One Mile Single Track of a Two-Track Road Compound Catenary.

Tangent 300′ span	Curve 0°–1′ to 1°–0′ 300′ span	Curve 1°–1′ to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–1′ 200′ span	Curve over 4°–1′ 200′ span with pull-off pole
$8,595.00	$8,805.00	$9,460.00	$10,460.00	$12,480.00	$17,225.00

TABLE 15—*Continued.*

COST FOR CATENARY CONSTRUCTION.

Cost for One Mile Single Track of a Two-Track Road Single Catenary.

Tangent and curves up to 2°–30′ 300′ span	Curve 2°–31′ to 3°–30′ 260′ span	Curve 3°–31′ to 4°–30′ 200′ span	Curves above 4°–30′ with pull-off pole
$6,860.00	$7,555.00	$9,692.50	$14,425.00

Cost for an Anchor—and Sectionalizing—Bridge.

	Compound catenary			Single catenary 2-track
	6-track	4-track	2-track	
Steel	$3,200.00	$1,600.00	$900.00	$620.00
Concrete	2,000.00	1,270.00	960.00	700.00
Floor on upper deck of bridge	200.00	160.00	100.00	100.00
Control apparatus and connections	8,000.00	6,300.00	4,500.00	4,500.00
Sectionalizing	600.00	400.00	200.00	200.00
Total	$14,000.00	$9,730.00	$6,660.00	$6,120.00

TABLE 16.

COST FOR CATENARY CONSTRUCTION.

One mile of four-track single catenary	Tangent 300′ span	Curve up to 2°–0′ 300′ span	Curve 2°–1′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–0′ 200′ span	Curve above 4°–1′ 200′ span with pull-off
Steel	$8,800.00	$11,830.00	$13,490.00	$17,500.00	$20,500.00
Concrete	2,930.00	3,940.00	4,200.00	5,640.00	8,640.00
Catenary material	7,035.00	7,193.40	7,260.00	7,415.00	8,170.00
Catenary labor	1,237.60	1,311.50	1,320.00	1,339.00	1,540.00
Total	$20,002.60	$24,274.90	$26,270.00	$31,894.00	$38,850.00

One mile of single track of a 4-track road	Tangent 300′ span	Curve up to 2°–0′ 300′ span	Curve 2°–1′ to 3°–0′ 260′ span	Curve 3°–1′ to 4°–0′ 200′ span	Curve above 4°–1′ 200′ span with pull-off
Single catenary	$5,000.15	$6,068.74	$6,567.50	$7,973.50	$9,712.50

Anchor and sectionalizing bridge for four track single catenary.	Steel	$1,200.00
	Concrete	960.00
	Floor on upper deck of bridge	160.00
	Control apparatus and connections	6,300.00
	Sectionalizing	400.00
	Total	$9,020.00

TABLE 17.

THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD COMPANY. STATISTICS OF ELECTRICAL OPERATION—NEW YORK AND SHORE LINE DIVISIONS. FOR THE MONTH OF NOVEMBER, 1914, COMPARED WITH THE MONTH OF OCTOBER, 1914.

Cos Cob Power House.

	November		October	
	Total	Per KWH	Total	Per KWH
Coal consumed (tons)	12,439.44	2.78 lbs.	12,280.84	2.75 lbs.
Water consumed (gallons)	38,778,000	4.33 gal.	35,835,000*	4.01 gal.*
Cost of coal	$34,084.07	.381c	$33,526.69	.375c
Cost of water	1,582.15	.017	5,015.55*	.057*
Cost of other supplies	317.20	.004	655.85	.007
Maintenance of power plant and machinery	3,655.27	.041	3,434.87	.038
Wages and salaries	6,056.62	.068	6,704.00	.075
Total Cost, Maintenance and operation	45,695.31	.511	49,336.96*	.552*
Fixed charges (interest, taxes and insurance)	16,106.89	.180	16,106.89	.180
Total cost	61,802.20	.691	65,443.85*	.732*
Power Consumption (KWH)				
Passenger Service (Elec. Locos.)	2,894,465		3,072,145	
Passenger Service (M. U. Cars)	630,039		499,367	
Freight Service	1,508,306		1,494,082	
Switching Service	984,255		848,613	
Non-Revenue Service	10,340		6,191	
Total used by Electric Locomotives and Motor Cars	6,027,405		5,920,398	
Signals	107,465		117,443	
Other company purposes	389,652		399,401	
Line loss	543,235		617,804	
Total used for company purposes	7,067,757		7,055,048	
New York, Westchester & Boston	676,144		636,058	
Other companies	1,205,699		1,255,139	
Total power used	8,949,600		8,946,245	
Maximum daily output	Tuesday, November 24th		Friday, October 30th	
	343,300 KWH		316,630 KWH	
Maximum swing	30,000 KW		29,800 KW	
	Friday, Nov. 6—7.00 P.M.		Sunday, Oct. 4—8.27 A.M.	
Maximum daily output	Tuesday, November 3rd		Sunday, October 18th	
	249,800 KWH		256,155 KWH	
Average Daily Output	301,902 KWH		288,589 KWH	
Power Purchased from N. Y. C.				
Power purchased (K.W.H.)	1,244,021		1,306,017	
Cost of power	$16,097.67		$16,348.47	
Cost per K.W.H. (Cents)	1.294		1.252	
Total Power:				
Total power consumed (K.W.H.)	10,193,621		10,252,262	
Total cost of power (including fixed charges)	$77,899.87		$81,792.32*	
Cost per K.W.H. (cents) (charges)	.764		.798*	

*Revised.

TABLE

THE NEW YORK, NEW HAVEN

STATISTICS OF ELECTRICAL OPERATION
MONTH OF NOVEMBER, 1914.

Passenger

	Express trains.			
	Eastbound		Westbound	
	November	October	November	October
Train miles	49,436	50,385	53,768	54,032
Locomotive miles	82,298	85,220	88,898	89,162
Car miles	386,883	404,166	410,574	425,363
Ton miles	23,880,554	24,483,292	24,654,186	25,697,939
K. W. H. used	1,120,801	1,133,588	1,231,060	1,220,947
Locomotive miles per train mile	1.66	1.69	1.65	1.65
Car miles per train mile	7.83	8.02	7.64	7.87
K. W. H. per train mile	22.67	22.50	22.90	22.60
K. W. H. per locomotive mile	13.62	13.30	13.85	13.70
K. W. H. per car mile	2.90	2.80	3.00	2.87
K. W. H. per 1000-ton mile	46.93	46.30	49.93	47.51

Operating

	Locomotive repairs		Power	
	Nov.	Oct.	Nov.	Oct.
Trains hauled by locomotives:				
Cost per train mile (cents)	17.15	13.80	19.33	19.89*
Cost per locomotive mile (cents)	10.61	8.56	11.96	12.29*
Cost per car mile (cents)	2.45	1.93	2.76	2.79*
Multiple-unit trains:				
Cost per train mile (cents)	15.27	11.83	11.39	11.42*
Cost per motor car mile (cents)	10.51	7.98	7.84	7.70*
Cost per car mile (cents)	4.32	3.12	3.22	3.01*

*Revised.

18.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.
COMPARED WITH MONTH OF OCTOBER, 1914.

Service.

Local trains				Multiple-unit trains			
Eastbound		Westbound		Eastbound		Westbound	
November	October	November	October	November	October	November	October
29,128	32,941	23,839	28,622	21,569	19,338	22,552	19,363
41,148	45,008	31,558	39,722	29,937	28,504	32,220	28,857
157,770	182,564	137,502	172,338	76,544	74,004	79,292	72,793
7,314,489	8,444,023	6,432,307	7,812,994	5,093,352	4,755,814	5,296,525	4,634,919
643,284	719,423	524,871	651,374	346,385	305,267	341,496	279,137
1.41	1.37	1.32	1.39	1.39	1.47	1.43	1.49
5.42	5.54	5.77	6.02	3.55	3.83	3.52	3.76
22.09	21.84	22.02	22.76	16.06	15.79	15.14	14.42
15.63	15.98	16.63	16.40	11.57	10.71	10.60	9.67
4.08	3.94	3.82	3.78	4.53	4.12	4.31	3.83
87.95	85.20	81.60	83.37	68.01	64.19	64.48	60.22

Costs.

Locomotive Supplies		Engine house Expenses		Enginemen		Trainmen		Total	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
2.23	1.53	.57	.54	8.81	8.37	9.51	9.55	57.60	53.68*
1.39	.95	.38	.34	5.41	5.20	5.88	5.91	35.63	33.25*
.32	.21	.08	.08	1.26	1.17	1.36	1.34	8.23	7.52*
.24	.16	.91	.78	5.17	5.20	8.84	7.53	41.82	36.92*
.17	.11	.62	.53	3.56	3.51	6.08	5.08	28.78	24.91*
.07	.04	.25	.21	1.46	1.37	2.52	1.98	11.85	9.73*

TABLE

THE NEW YORK, NEW HAVEN

STATISTICS OF ELECTRICAL OPERATION—
MONTH OF NOVEMBER, 1914.

Freight

	Fast freight.			
	Eastbound		Westbound	
	November	October	November	October
Train miles	3,283	3,484	4,954	7,576
Locomotive miles	3,283	3,486	8,042	11,128
Loaded car miles	130,147	140,202	159,377	219,435
Empty car miles	335	203	60,545	106,040
Caboose miles	3,283	3,484	4,954	7,576
Ton miles	4,399,743	4,589,492	5,941,893	8,677,627
K. W. H. used	108,749	112,033	186,401	265,088
Locomotive miles per train mile	1.00	1.00	1.62	1.47
Loaded car miles per train mile	39.64	40.24	32.17	28.96
Empty car miles per train mile	1.10	1.06	13.22	15.00
Ton miles per train mile	1,340.16	1,317.31	1,199.41	1,145.41
Ton miles per locomotive mile	1,340.16	1,316.55	738.86	779.80
Percentage of tonnage to rating	96%	95%	.....	.....
Ton miles per hour	26,779	27,335	19,109	18,092
Average Speed (m. p. h.)	19.98	20.75	15.93	15.79
K. W. H. per train mile	33.12	32.16	37.63	34.99
K. W. H. per locomotive mile	33.12	32.11	23.18	23.82
K. W. H. per car mile	.81	.78	.83	.80
K. W. H. per 1000-ton miles	24.72	24.41	31.37	30.54

Ton miles are based on weight of trailing load.
Percentage of tonnage to rating is found by dividing the total tonnage of trains as they leave
Ton miles per hour is found by dividing ton-miles by the total running time of trains between
Average speed is found by dividing train-miles by total running time of trains between terminals.

Operating

	Locomotive repairs		Power	
	Nov.	Oct.	Nov.	Oct.
Cost per train mile (cents)	15.51	15.98	28.51	27.90*
Cost per locomotive mile (cents)	9.69	10.19	17.82	17.79*
Cost per 1000-ton miles (cents)	9.95	10.16	18.30	17.73*

* Revised.

19.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.
COMPARED WITH MONTH OF OCTOBER, 1914.

Service.

Slow Freight				Local Freight			
Eastbound		Westbound		Eastbound		Westbound	
November	October	November	October	November	October	November	October
8,485	9,177	6,152	4,880	2,880	3,240	2,933	3,240
16,529	18,038	11,269	9,824	2,956	3,321	3,012	3,321
484,644	529,559	203,556	209,889	29,965	33,893	32,990	37,339
57,346	59,801	184,978	177,831	16,304	16,339	12,072	20,456
8,485	9,177	6,152	4,880	2,880	3,240	2,933	3,240
21,121,401	22,885,161	10,496,232	10,448,521	1,301,163	1,414,569	1,432,065	1,702,877
566,983	571,972	340,830	294,602	118,423	110,757	106,650	114,828
1.95	1.97	1.83	2.01	1.03	1.03	1.03	1.03
57.12	57.71	33.09	43.01	10.40	10.46	11.25	11.52
7.76	7.52	31.07	37.44	6.66	6.04	5.12	7.31
2,489.26	2,493.75	1,706.15	2,141.09	451.79	436.60	488.26	525.58
1,277.84	1,268.72	931.43	1,063.57	440.18	426.55	475.45	512.76
94%	93%	.....	.....	.....	.....	.....	.....
26,008	27,912	18,637	23,297	2,614	2,679	3,423	3,622
10.45	11.19	10.92	10.88	5.79	6.14	7.01	6.89
66.82	62.32	55.40	60.37	41.12	34.18	36.36	35.44
34.30	31.71	30.24	29.99	40.06	33.35	35.41	34.58
1.03	.96	.86	.75	2.41	2.07	2.22	1.88
26.84	24.99	32.47	28.20	91.01	78.29	74.47	67.43

Harlem River by the rating of locomotive hauling those trains.
terminals.

Costs.

Locomotive Supplies		Engine house Expenses		Enginemen		Trainmen		Total	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
.54	.63	.48	.58	10.66	10.44	17.83	17.46	73.53	72.99*
.34	.40	.30	.37	6.67	6.66	11.14	11.13	45.96	46.54*
.35	.40	.31	.37	6.84	.663	11.45	11.09	47.20	46.38*

TABLE

THE NEW YORK, NEW HAVEN

STATISTICS OF ELECTRICAL OPERATION—

FOR THE MONTH OF NOVEMBER, 1914.

Line and Equipment

	Line											
	Catenary insulator failures				Dead end failures				Other line failures			
	Nov.		Oct.		Nov.		Oct.		Nov.		Oct.	
	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay
Between Woodlawn and Stamford	1	22	1	14	..	..	..	..	1	..	1	8
Between Stamford and New Haven	2	..	..	..	..	..	..	..	3	41	4	47
On New Canaan Branch	..	..	..	..	..	..	..	..	..	..	..	..
On Harlem River Branch	..	..	..	..	..	..	..	..	1	13	1	7
In Yards	..	..	..	..	3	..	1	..	2	7	4	..
Total	3	22	1	14	3	..	1	..	7	61	10	62

Equipment

Class of service	Heated parts		Broken parts	
	Nov.	Oct.	Nov.	Oct.
Passenger	1	4	2	1*
Freight	1	2	1	2
Switch	0	0	0	0
Multiple	3	0	2	1 *
Total	5	6	5	4*

20.

AND HARTFORD RAILROAD COMPANY.

NEW YORK AND SHORE LINE DIVISIONS.

COMPARED WITH THE MONTH OF OCTOBER, 1914.

Failures.

failures

Equipment failures				Signal failures				Outside interference				Failures of employes				Total failures			
Nov.		Oct.		Nov.		Oct.		Nov.		Oct.		Nov.		Oct.		Nov.		Oct	
No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay	No.	Total Delay
..	...	1	143	.	..	1	...	2	..	3	..	..	..	..	..	4	2	7	165
6	141	5	23	1	15	..	..	2	..	..	..	..	..	..	..	14	197	9	70
..	...	..	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..	...	...
..	...	..	...	..	..	..	..	..	..	..	..	..	..	..	..	1	13	1	7
4	28	1	...	..	..	..	..	..	..	..	..	1	..	..	..	10	35		...
10	169	7	166	1	15	1	..	4	..	3	..	1	..	..	..	29	267	23	242

Failures.

Grounds		Miscellaneous		Total failures		Miles per failure		Minutes detention per failure	
Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.	Nov.	Oct.
20	25*	12	6	35	36*	7,071	7,328*	11	13*
3	2	0	1	5	7	13,183	9,506	56	60
0	0	0	0	0	0	40,964	39,624	0	0
2	0	11	11	18	12*	3,554	4,331**	18	7*
25	27*	23	18	58	55*	7,213	7,672*	17	18*

Vertical Rowland Mounting for Concave Grating. A. S. KING. (*Astrophys. Journ.*, xc, 205.)—Details are given of new structural features embodied in the installation of a 15-foot concave grating on the Rowland plan, but with the plane of dispersion vertical instead of the more usual horizontal disposition. The arrangement permits placing the grating in a pit beneath the laboratory floor, thereby obtaining the constancy of temperature which has proved highly advantageous with plane grating spectrographs. The apparatus is so constructed that it may be operated in a fully-lighted room, and occupies a minimum of floor space. An ingenious arrangement is provided to allow for the variable counterpoise necessary on account of the changing angle of the beam to the vertical.

Ultraviolet Band in Ammonia Spectrum. E. P. LEWIS. (*Astrophys. Journ.*, xl, 154.)—The ultraviolet band λ3295–λ3432, described by Eder as the principal band of ammonia, has been detected by the author in vacuum-tube spectra of mixtures of nitrogen and hydrogen at all pressures up to 70 cm., and becomes specially prominent when self-induction is employed. It was not found with nitrogen free from hydrogen, or hydrogen free from nitrogen. Small traces of oxygen appear to have no effect, while large quantities destroy it. Whereas the greenish-red band is found only on the first sparking, the ultraviolet band persists for long periods.

Muffling Exhaust by Turbine Wheel. ANON. (*Sci. Amer.*, cxii, No. 3, 63.)—A new form of muffler for the exhaust gases of automobile and aëroplane engines has just been brought out by a Rochester firm. It consists of a small turbine wheel which is revolved rapidly by the impinging exhaust gas, breaking its force and converting the explosive noise into a slight hissing sound. Part of the gases is caught by a baffle plate, but the back pressure caused by this is so small as to be almost negligible. There is no loss in power from the motor, and the inertia of the revolving wheel assists in drawing the exhaust gas from the pipe and manifold, even after the force of the piston movement has passed. The device takes a smaller space than the ordinary baffle plate muffler.

A Self-adjusting Piston Ring. (*Sci. Amer.*, cxii, No. 3, 63.)—Packing the pistons in an internal-combustion engine is not an easy matter, and many are the plans made to circumvent the necessity of continually adjusting and packing loose pistons. A novel type of piston ring has been invented by a Boston manufacturer, in which the use of radial holes serves to equalize the pressure between the outer and inner surfaces. The piston rings have a slightly conical shape, which causes them to be forced tightly against the cylinder walls during the compression stroke, when the tendency of "downward crowding" is at its highest.

A METHOD FOR CALCULATING THAT PART OF THE RECOIL MOMENTUM OF A GUN WHICH IS DUE TO THE ACTION OF THE GASES AFTER THE PROJECTILE LEAVES THE MUZZLE.*

BY

WM. S. FRANKLIN,

Professor of Physics, Lehigh University.
Member of the Institute.

THE object of this paper is to develop a simple point of view in the mathematical theory of wave motion, to illustrate the point of view by several simple problems, and to use the point of view in the determination of that part of the recoil momentum of a gun which is produced by the action of the gases after the projectile leaves the muzzle of the gun.

It is helpful in the study of wave motion to base everything upon a consideration of the *velocity* and *distortion* [1] of the medium at a point, because a kind of mathematical symmetry is realized thereby. To do this in the case of a transverse wave on a stretched wire or string, however, seems rather strange, because it is natural to think of a wave on a wire as a travelling bend, and this point of view directs the attention primarily to the *displacement* of the wire at each point rather than to its sidewise velocity and abnormal degree of stretch. The normal or zero condition of a stretched wire is taken as the degree of stretch of the wire as it lies in equilibrium in a straight line between its end supports as shown by the full line in Fig. 1.

The well-known expression for a pure wave travelling from left to right along a stretched string is:

$$y = f(x - ct)$$

* Communicated by the Author.

[1] The state of affairs at a point in a wave can be specified by giving the *velocity of the medium* and the *deformation or strain of the medium* at the point; or by giving the *velocity of the medium* and the *stress in the medium* at the point. An example of the first is to specify the state of affairs on a wire by giving its sidewise velocity and degree of stretch, and an example of the second is to specify the state of affairs in an air wave by giving the velocity of the air and the excess-pressure.

where y is the sidewise displacement of the string at the point whose abscissa is x, and c is the velocity of wave propagation. Therefore the sidewise velocity of the wire at a point is:

$$v = \frac{dy}{dt} = -cf'(x - ct)$$

and the abnormal degree of stretch of the wire at a point is:

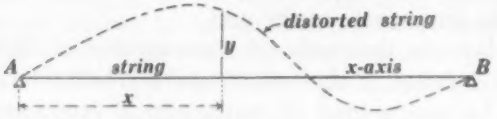
$$s = \frac{dy}{dx} = f'(x - ct).$$

Whence we get:

$$\frac{v}{s} = -c \tag{1}$$

for a pure wave travelling from left to right; and by using the well-known expression for a pure wave travelling from right to

FIG. 1.



left, namely, $y = F(x + ct)$, we get in a similar manner:

$$\frac{v}{s} = +c \tag{2}$$

for a pure wave travelling from right to left.

A pure wave travelling to the right is therefore a configuration of sidewise velocity and stretch in which v/s is at each point equal to $-c$, and a pure wave travelling to the left is a configuration of sidewise velocity and stretch in which v/s is at each point equal to $+c$.

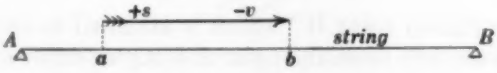
A rectangular wave is one in which v (and also s) has the same value everywhere, and it is largely waves of this type which are used in the following examples. Such a wave is conveniently symbolized in Fig. 2. The arrow in Fig. 2 indicates that at every point between a and b the wire has a slope or stretch $+s$ and a downward velocity v. To represent the travel of the entire configuration to the right at wave velocity c we imagine the arrow itself to travel at velocity c.

A long-drawn-out rectangular wave which issues continuously

from a point on a wire, like a ribbon issues continuously from the mouth of a prestidigitateur, is called a *ribbon wave*.

Before proceeding to the consideration of the classical problem of the plucked string, as an example, it is necessary to determine the mode of reflection of a pure wave at either end of a stretched string. Thus the rectangular wave of Fig. 2 is shown

FIG. 2.



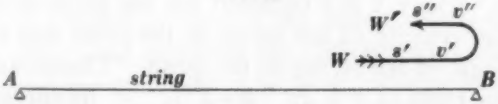
partly turned back or reflected from the end B of the string in Fig. 3. The state of stretch and the state of sidewise velocity in the original wave W are represented by s' and v' respectively; and the state of stretch and the state of sidewise velocity in the reflected wave W'' are represented by s'' and v'' respectively. The condition which must necessarily be satisfied at B is that the actual sidewise velocity of the wire be zero there, whereas the stretch or slope can have any value whatever. Also v'/s' must be equal to $-v''/s''$ according to equations (1) and (2). Therefore we have:

$$v' + v'' = 0 \tag{3}$$

$$\frac{v'}{s'} = -\frac{v''}{s''} \tag{4}$$

from which we find $v'' = -v'$ and $s'' = s'$. That is, the wave is reflected from the fixed end B with reversal of v but without reversal of s.

FIG. 3.



The Problem of the Plucked String.—To determine the motion of a plucked string is to discover a number of particular solutions of the differential equation of motion of the string, such that when these solutions are added together (thus giving a new solution) the initial conditions are satisfied when $t = 0$ and the boundary or end conditions are satisfied at all times. Let us therefore consider the following particular solutions of the differential equation of motion of a string as shown in Fig. 4:

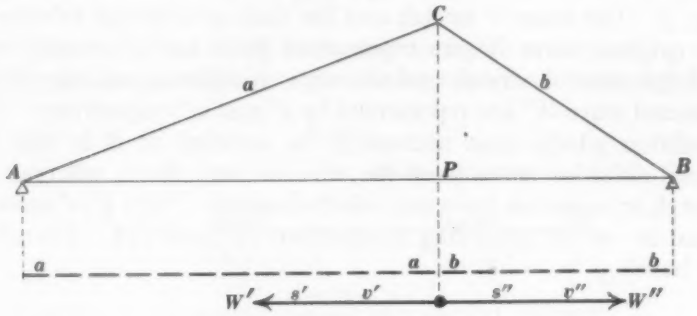
(*a*) The dotted line *a* which represents the initial uniform stretch of the portion *AC* of the string is a particular solution of the differential equation of motion of the string.[2]

(*b*) The dotted line *b* which represents the initial uniform stretch of the portion *CB* of the string is a particular solution.

(*c*) The ribbon wave *W''* which is assumed to shoot out continuously to the right from the point *P* is a particular solution; and

(*d*) The ribbon wave *W'* which is assumed to shoot out continuously to the left from the point *P* is a particular solution.

FIG. 4.



If by choosing proper values for s', s'', v' and v'' and adding these four particular solutions together we can satisfy all of the necessary conditions, then we will have found the complete solution of our problem.

The energy stream at any point on the wire is equal to the product kvs,[3] where k is a constant for the given string, v is the total sidewise velocity of the string at the point and s is the total stretch or slope of the string at the point. Therefore the energy stream on the right of P is $kv''(b+s'')$, and the energy stream on the left of P is $kv'(a+s')$; and these energy streams are necessarily equal to each other. Therefore we have:

$$v'(a+s') = v''(b+s'') \tag{5}$$

[2] In fact, any equilibrium condition of a portion of the string is a particular solution for that portion.

[3] This is exactly analogous to the expression for the energy stream on an electrical transmission line, namely, EI where E is the electromotive force across the line and I is the current in the line.

Furthermore, according to equations (1) and (2), we have:

$$\frac{v'}{s'} = +c \tag{6}$$

$$\frac{v''}{s''} = -c \tag{7}$$

Also the string will break at P unless we have:

$$v' = v'' \tag{8}$$

and this is therefore a necessary equation of continuity. The initial slopes a and b and the wave velocity c are given, so that equations (5) to (8) determine v', v'', s' and s'', giving:

$$s'' = -s' = \tfrac{1}{2}(a-b) \tag{9}$$

and

$$v'' = v' = -\tfrac{1}{2}(a-b)c \tag{10}$$

The values of a and b are, of course, both expressible in terms of the initial displacement of the point P and the lengths of the segments AP and PB of the string.

It is evident that the solution shown in Fig. 4 satisfies the initial conditions, because the two ribbon waves do not exist at $t = 0$.

Also the boundary or end conditions are always satisfied by the reversal of v every time either ribbon wave is reflected at A or B.

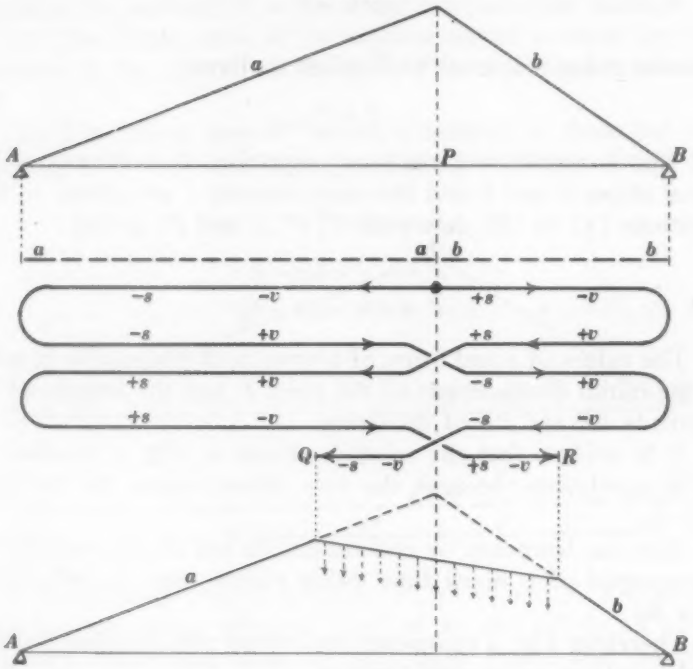
Therefore Fig. 4 represents the correct and complete solution of the problem under consideration.

The configuration and state of motion of the string at any instant may be found by adding together the initial conditions a and b and any number of laps of the ribbon waves W' and W''. Thus Fig. 5 shows the extent of the ribbon waves after sufficient time has elapsed for each ribbon wave to travel a little more than twice the length of the string, and the actual configuration and state of motion of the string at this instant is shown at the bottom of Fig. 5. This must not be thought of as a graphical solution of the problem of a plucked string; it is an analytical solution in which any desired result having to do with the motion of the string may be calculated by arithmetical methods pure and simple.

A pipe closed at both ends contains slightly compressed air, and one end of the pipe is suddenly opened wide. It is required to determine the motion of the air in the pipe. The complete

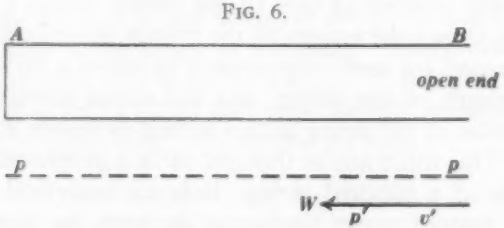
solution of this problem is shown in Fig. 6, in which the dotted line p represents the initial uniform compression (a particular solution of the differential equation of motion of the air in the

FIG. 5.



tube), and the arrow W represents a ribbon wave which shoots towards the left from the open end of the tube and is repeatedly

FIG. 6.



reflected at both ends of the tube (a particular solution of the differential equation of motion of the air in the tube).

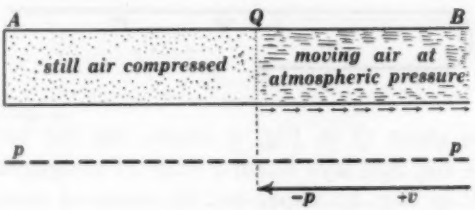
The initial conditions are evidently satisfied, because at $t = 0$ the ribbon wave does not exist.

The energy stream at B is $(p+p')v'$, and it must be equal to zero.[4] Therefore $p' = -p$.

The boundary or end conditions are always satisfied if the ribbon wave is reflected with reversal of v at the closed end of the tube and with reversal of p at the open end of the tube; that is, the pressure will always be zero (atmospheric pressure) at B and the velocity of flow will always be zero at A.

The ratio p/v in a pure wave in air is equal to $+\sqrt{\kappa\delta P}$ or to $-\sqrt{\kappa\delta P}$ according as the wave is travelling to right or to left respectively; and the velocity of wave propagation is $\sqrt{\frac{\kappa P}{\delta}}$; where κ is the ratio of the specific heats of air, δ is the density of the air, and P the absolute pressure.

FIG. 7.



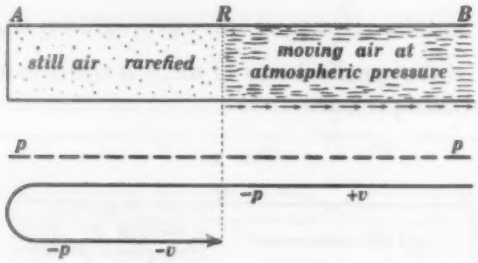
The actual motion of the air in the tube is as follows: The dividing line Q, Fig. 7, between the still air and the moving air may be called a *wave sheet*. As this wave sheet travels from B to A in Fig. 7 it wipes out the excess-pressure p and lays down a uniform outward flow at velocity v. When Q reaches A the entire tube is filled with air at atmospheric pressure flowing outwards at uniform velocity v. There is then a sudden drop of pressure at A, and as the wave sheet R travels from A to B in Fig. 8 it wipes out the velocity v and leaves behind it a region of still and rarefied air.

[4] To place the energy stream at B equal to zero is to assume that the energy stream due to convection as negligible in comparison with the energy stream due to coexistence of p and v. The energy stream due to convection is the carrying of the energy of the compressed and flowing air along with the air.

Another point of view is to consider that the air-pressure at the open end of the tube must drop instantly to zero (atmospheric pressure) and remain equal to zero, so that $p + p' = 0$. It is beyond the scope of this discussion to consider the Helmholtz end-effect, as it is also to consider that the reflection at the open end of a tube is not complete.

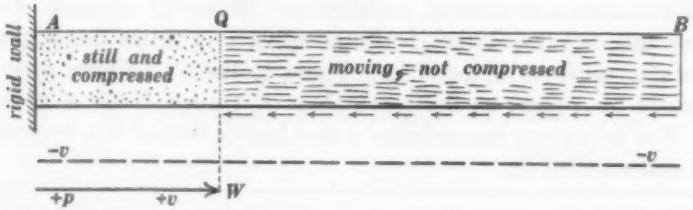
The Rebounding of a Steel Rod Which Moves Endwise and Strikes a Rigid Wall.—The complete solution of this problem is shown in Fig. 9. The dotted line $-v$ represents the initial velocity, and the arrow W represents a ribbon wave of compression p and velocity $+v$. The wave sheet Q travels at velocity $\sqrt{\frac{E}{\delta}}$, and the ratio p/v is equal to $\sqrt{\delta E}$, where E is the stretch modulus and δ is the density of the steel.

FIG. 8.



The wave sheet Q in Fig. 9 wipes out the initial uniform motion of the rod and lays down a state of compression; and the wave sheet R in Fig. 10 wipes out the state of compression and lays down a state of uniform motion to the right. When the wave sheet R reaches the end B of the rod the entire rod is free of compression and moving at velocity v away from the wall.

FIG. 9.



An Interesting Case of Wave Motion on a Cast-iron Rod.—A cylindrical slug of length L moving at velocity $2v$ strikes squarely against the end of a long rod of the same material, the diameter of the rod being the same as the diameter of the slug.

Fig. 11 shows the initial state of affairs resolved into two pure waves as represented by the two arrows W and W'. A

positive value of p represents *compression* (force per unit area) and a negative value of p represents *tension*.

Fig. 12 shows the wave W' shooting outwards (to the right) and the wave W receding (travelling to the left); and Fig. 13 shows the final pure wave W' of length $2L$ which has been produced by the impact of the slug.

FIG. 10.

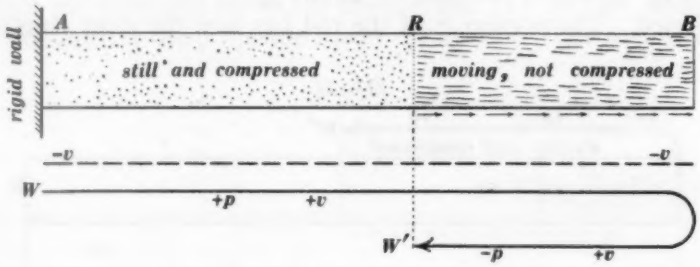


FIG. 11.

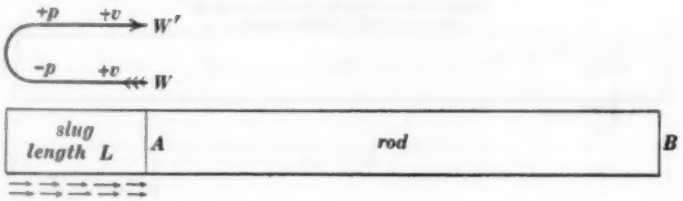


FIG. 12.

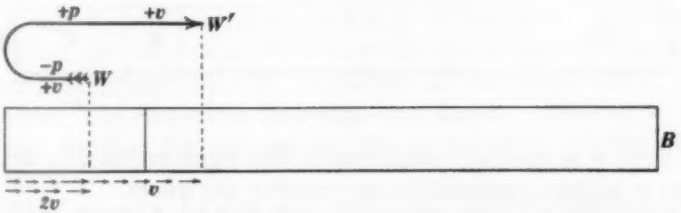


Fig. 14 shows the pure wave W' after it has left the slug high and dry, as it were. The slug has come completely to rest and is neither under compression nor under tension. The wave W' in Fig. 14 will soon reach the end B of the rod, where it will be turned back or reflected.

Fig. 15 shows the wave W' partly turned back or reflected as

the pure wave W''. The compression in W' has been reversed by reflection and converted into an equal tension in the wave W'', but the velocity v has not been reversed. The portion F of the rod is therefore neither under compression nor under tension, but it is moving to the right at velocity $2v$. The portion E of the rod is moving uniformly to the right at velocity v and it is under compression p.

Fig. 16 shows the state of affairs when the wave W' is half reflected. The portion F of the rod has now the same length as

FIG. 13.

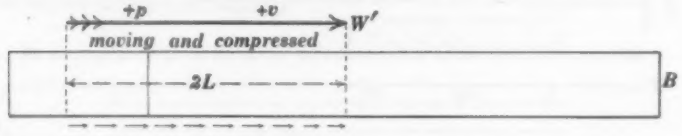


FIG. 14.

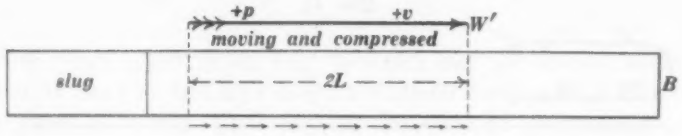
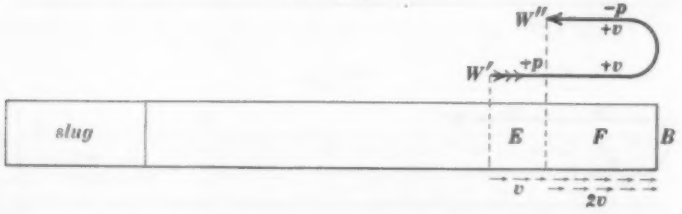


FIG. 15.



the slug, it is moving uniformly to the right at velocity $2v$, and there is neither compression nor tension anywhere.

Immediately after the state of affairs which is shown in Fig. 16 the reflected wave W'' begins to show itself alone in the region G, Fig. 17, and in this region G the material of the rod is under a tension which is numerically equal to the compression in the wave W'.

The rod, being made of cast iron, can withstand a very great compression, but it cannot withstand a very great tension. There-

fore, if the original velocity of the slug is sufficiently large the incipient tension in the narrow region G will be more than the cast iron can stand, and the portion F, Fig. 16, of the cast iron will fly off.

THE PROBLEM OF GUN RECOIL.[5]

The total recoil momentum of a gun may be conveniently considered in two parts; namely, (a) the part which is produced before the projectile leaves the muzzle, and (b) the part which is produced after the projectile leaves the muzzle. The part (b) of

FIG. 16.

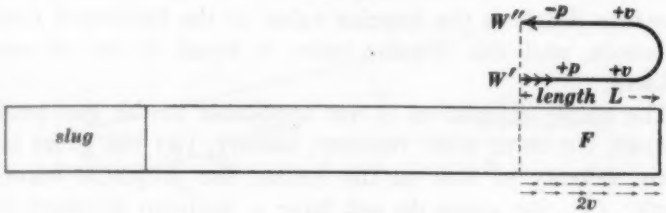
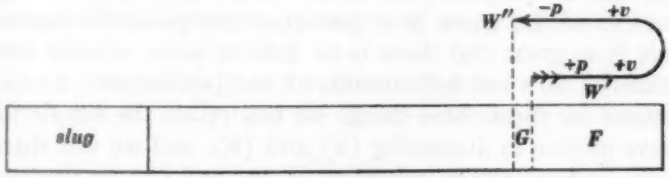


FIG. 17.



the recoil momentum has heretofore been calculated by entirely irrational empirical formulas, and such formulas are very unreliable when the conditions for which the calculation is to be made depart perceptibly from the conditions of the experimental tests on which the empirical formulas are based. Following is a rational method for calculating the portion (b) of the recoil momentum:

If the gases in the gun were stationary and at a uniform pressure only slightly above atmospheric pressure at the instant of opening the muzzle of the gun, then Figs. 6, 7, and 8 would give us the solution of our problem. The excess-pressure p would continue to exist unaltered at the breech A until the wave sheet Q

[5] Throughout this paper f.p.s. units are used; length in feet, mass in pounds, time in seconds, force in poundals, energy in foot-poundals, pressure in poundals per square foot, density in pounds per cubic foot, etc.

of Fig. 7 had travelled from B to A, and then the pressure at A would drop suddenly to a value below atmospheric pressure. In the actual gun problem it is not necessary to consider pressure values at A below atmospheric pressure; it is only necessary to determine the march [6] of pressure values at the breech from the enormously high initial value down to atmospheric pressure P. Therefore we will ignore pressure values below P in this preliminary discussion. The force acting on the breech A in Fig. 7 is pq where q is the sectional area of the bore of the gun, and this force continues to act for L/c seconds after end B is opened, where L is the length of the gun and c is the velocity of sound. Therefore pqL/c is the impulse value of the backward force on the breech, and this impulse value is equal to the momentum produced.

The above calculation is not applicable to the gun problem, however, for three chief reasons; namely, (a) the gases have a certain velocity of flow at the instant the projectile leaves the muzzle; (b) the gases do not have a uniform pressure at the instant that the projectile leaves the muzzle; and (c) the range of expansion of the gases in a gun after the projectile leaves the muzzle is so great that there is no definite wave velocity and the velocities of flow reach thousands of feet per second. In making allowance for these three things we will retain the simple theory of wave motion in discussing (a) and (b), and we will then discuss (c) and secondary influences of (a) and (b) on the basis of a modified wave theory.

Discussion of Initial Velocity of Flow of Gases.—A gun tube is filled with gas which is everywhere at atmospheric pressure, but the gas is moving at small velocity v, towards the muzzle, the value of v being proportional to $(L - x)$, so that we may write:

$$v = a(L - x) \tag{11}$$

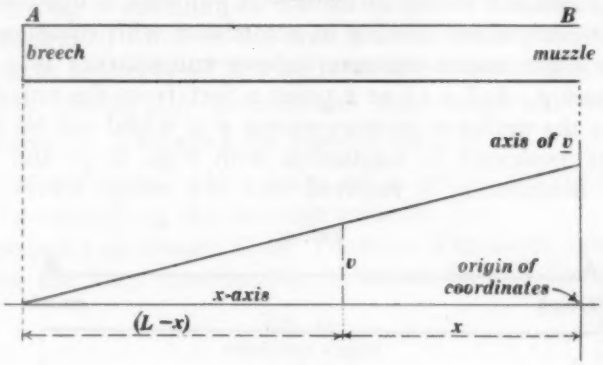
where a is a known constant. The specified velocity distribution is represented in Fig. 18, and (with normal atmospheric pressure everywhere) it constitutes what is called an *impure wave*,[7] which

[6] To determine the *march* of a varying quantity is to determine it as a function of elapsed time.

[7] See Franklin and MacNutt's "Advanced Electricity and Magnetism," p. 222. The Macmillan Company, 1915.

is resolvable into two pure wave components, one of which travels towards the muzzle and involves half of the specified velocity of flow and a *pressure rise* equal to $\frac{1}{2}a(L-x)\sqrt{\kappa\delta P}$; and the other of which travels towards the breech and involves the other

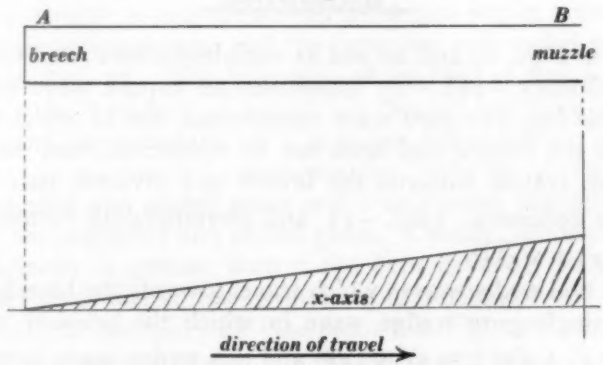
FIG. 18.



half of the specified velocity of flow and a *pressure drop* equal to $\frac{1}{2}a(L-x)\sqrt{\kappa\delta P}$. These two pure waves are represented in Figs. 19 and 20.

The wave in Fig. 19 is travelling away from the breech, and, although it is partially reflected at the open end B of the tube, it

FIG. 19.

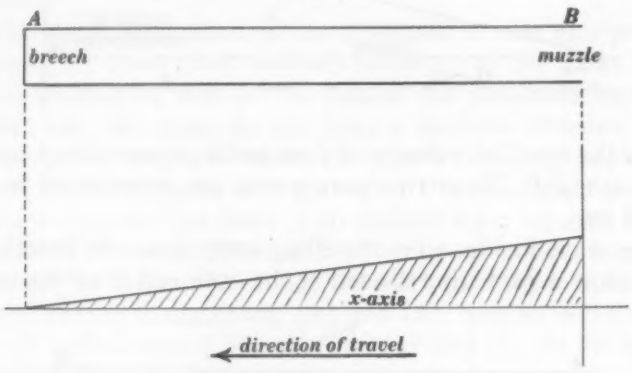


finally reaches the breech too late to modify the march of pressure values at A in which we are interested. The wave in Fig. 20 is reflected at the breech with reversal of v but without reversal of pressure drop. Therefore, inasmuch as the actual drop of pres-

sure at the breech is the sum of the pressure drops in the original and reflected waves, it is evident that this wave causes a uniform drop of pressure at the breech which amounts to $aL\sqrt{\kappa\delta P}$ during the time required for sound to travel from B to A.

Discussion of Combined Effect of Initial Variation of Pressure and Initial Velocity of Flow.—A gun tube is filled with gas which is everywhere moving in accordance with equation (11), and the slight excess-pressure (above atmosphere) is p at the breech and $p - b(L - x)$ at a point x feet from the muzzle. In this case the uniform pressure-excess p is wiped out by a wave sheet, as explained in connection with Figs. 6, 7, and 8; the velocity distribution is resolved into two wedge waves, as in-

FIG. 20.



dicated in Figs. 19 and 20 and as explained above; and the pressure deficiency $-b(L-x)$ constitutes an impure wave which is resolvable into two pure wave components, one of which travels towards the muzzle and need not be considered, and the other of which travels towards the breech and involves half of the pressure deficiency $\frac{1}{2}b(L-x)$ and corresponding *outward flow* $\frac{1}{2}b(L-x) \div \sqrt{\kappa\delta P}$.

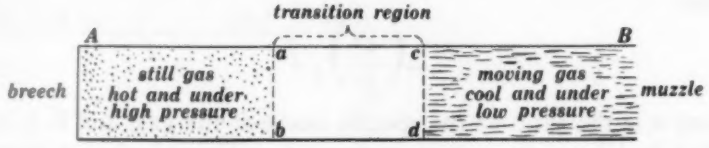
The two wedge waves which travel towards the breech merge into a single pure wedge wave in which the pressure drop is $\frac{1}{2}b(L-x) + \frac{1}{2}a(L-x)\ \sqrt{\kappa\delta P}$, and this wedge wave is reflected at the breech with reversal of v but without reversal of pressure drop. Therefore, inasmuch as the actual drop of pressure at the breech is the sum of the pressure drops in the original and reflected waves, it is evident that this wedge wave causes a uniform

drop of pressure at the breech which amounts to $bL + aL\sqrt{\kappa\delta P}$ during the time required for sound to travel from B to A; and then the wave sheet Q, as above explained, causes the pressure at the breech to drop suddenly to a value below atmospheric pressure.

According to this analysis the calculation of the impulse value of the backward force on the breech would be as follows: The force on the breech drops at a uniform rate from pq to $(p - bL - aL\sqrt{\kappa\delta P})q$ during L/c seconds and then drops suddenly to a value below P. Therefore the average value of the force during the L/c seconds is $(p - \frac{1}{2}bL - \frac{1}{2}aL\sqrt{\kappa\delta P})q$, and its impulse value is found by multiplying this average value by L/c.

Inadequacy of Simple Wave Theory.—The above simple calculations are very considerably in error, because there is no

FIG. 21.



definite wave velocity (velocity of sound) for so wide a range of expansion as that which takes place in the gases in a gun after the projectile leaves the muzzle. Indeed, the wave sheet Q in Fig. 7 is actually a long-drawn-out transition region between the hot and compressed gases and the expanded and cooled gases, as shown in Fig. 21. The boundary ab in Fig. 21 has a definite velocity (the "velocity of sound" in the hot and high pressure gases), and the boundary cd, if it exists, has a definite velocity, namely, $(c - v)$ where c represents the "velocity of sound" in the expanded and cooled gases and v represents the velocity of flow of the expanded and cooled gases. Usually, however, v (as here defined) is greater than c (as here defined), so that the boundary cd is carried out beyond the muzzle and lost.[8] Therefore when the boundary ab (the point r in Fig. 22) reaches the breech the transition region fills the entire gun tube.

[8] The carrying of the boundary cd out beyond the muzzle means that gas far above atmospheric pressure flows out of the muzzle, and it is the sidewise expansion of this gas which produces the mushroom cloud of smoke at the muzzle.

Gas at a very high pressure p_o fills a tube AB, Fig. 22, which is permanently closed at the end A. The other end B is closed by a piston which is released at $t = 0$. This piston is supposed to be without mass and its motion is supposed to be hindered by a force which is exactly equivalent to atmospheric pressure P exerted over its outside face. It is desired to determine the motion of the gas in the tube AB, friction being ignored. The initial distribution of pressure is represented by the curve $p_o p_o g$ in Fig. 22.

For each infinitesimal step of pressure drop an action essentially like that shown in Fig. 7 takes place. Consider, for example, the pressure drop from $p + \Delta p$ to p, where p is any pressure between p_o and P. The wave sheet (like Q in Fig. 7) which carries this pressure drop along travels, *with respect to the gas*, at the velocity of sound which corresponds to the state of the gas at pressure p; that is, at a velocity c which is given by:

$$c = \left(\frac{\kappa p_o^{\frac{1}{\kappa}}}{\delta_o} \right)^{\frac{1}{2}} p^{\frac{\kappa - 1}{2\kappa}} \tag{12}$$

where κ is the ratio of the specific heats of the gas, and δ_o is the initial density of the gas at pressure p_o. The velocity of flow v of the gas which has expanded adiabatically from p_o down to p is given by placing the kinetic energy per pound equal to the work done by adiabatic expansion per pound, whence:

$$\tfrac{1}{2} v^2 = \frac{p_o^{\frac{1}{\kappa}}}{\kappa \delta_o} \int_{p=p_o}^{p=p} p^{-\frac{1}{\kappa}} \cdot dp$$

which gives:

$$v^2 = \frac{2 p_o}{(\kappa - 1)\delta_o} \left[1 - (p_o p)^{\frac{\kappa - 1}{\kappa}} \right] \tag{13}$$

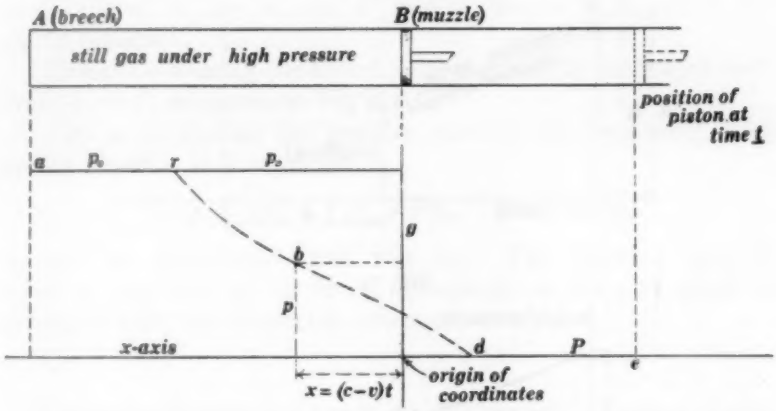
where v is the velocity of flow of the gases at the point x in Fig. 22. Substituting the values of c and v from equations (12) and (13) in the expression for x which is given in Fig. 22, namely, $x = (c - v)t$, we get an equation between x and p which is the equation to the dotted curve in Fig. 22, and the complete curve *arbde* in Fig. 22 is the curve of pressure distribution at the instant t.

Outline of Approximate Solution of the Gun Recoil Problem.

—The principle of superposition is not valid for the wave motion which takes place in the gases in a gun after the projectile leaves the muzzle; nevertheless, we use this principle in the following, and some of the correction terms make partial allowance for the invalidity of the principle.

Data.—At the instant $t = 0$, when the projectile leaves the muzzle of the gun, the pressure of the gas at the breech is p_0, the density of the gas is δ_0, and the ratio of the specific heats of the gas is κ. The pressure tapers off from p_0 at the breech to $(p_0 - bL)$ at the muzzle, and the velocity of flow of the gases as given by

FIG. 22.



the equation $v = a(L - x)$; a and b being given. In the following discussion p_0 and p refer to absolute pressures. The length of the gun tube is L and the sectional area of bore is q. The origin of coördinates is at the muzzle, the x-axis is the axis of the gun tube, and the abscissa x is measured from the muzzle towards the breech, as shown in Figs. 22 and 23.

Step 1.—Calculate the time t_1 required for the point r in Fig. 22 to travel from muzzle to breech, assuming average outward velocity of flow of gases during the whole time to be $\frac{1}{2}\,aL$, and assuming average wave velocity with respect to gases to be that which corresponds to a pressure equal to $p_0 - \frac{1}{2}\,bL$. That is, use this value for p in equation (12), calculate c, and then the average velocity of r with respect to the gun will be $c - \frac{1}{2}\,aL$, and the desired value of $t_1 = L/(c - \frac{1}{2}\,aL)$.

Remark.—During the time t_1 the pressure at the breech drops from p_o to $p_1 = p_o - bL - aL\sqrt{\kappa\delta_o p_o}$, as shown in Fig. 24.

Step 2.—Calculate from equation (13) the velocity of flow v corresponding to adiabatic expansion from p_o to $p = \frac{1}{2}(P + p_o)$; calculate the value of c corresponding to this value of p, using equa-

FIG. 23.

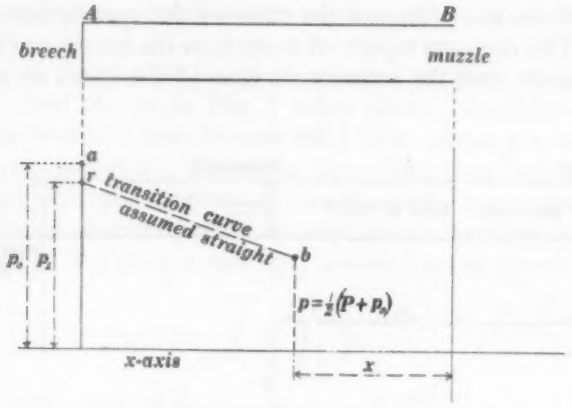
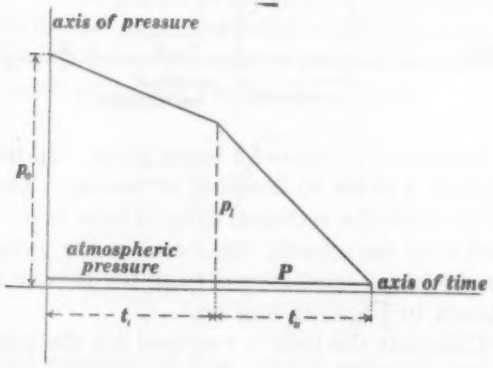


FIG. 24.



tion (12); and calculate the value of x in Fig. 23 corresponding to the instant when the point r in Fig. 22 has reached the breech; that is, after time t_1 has elapsed. The desired value of x is $(c - v)t_1$[9] *lessened* by the amount $v' t_1$, where v' is the average value of the initial velocity of flow between $x = 0$ and $x\ (c - v)t_1$.

[9] The values of c and v are those referred to in the same sentence.

Remark.—The state of affairs at $t = t_1$ is shown in Fig. 23, and we will now assume that the portion *rb* of the transition region [the point *r* having reached the breech, and the point *b* corresponds to $p = \frac{1}{2}(P + p_o)$,] travels to the left as a simple wave at velocity $c'' - v''$ with respect to the gun tube, and is reflected at the breech with reversal of velocity of flow but without reversal of pressure drop, where c'' is the velocity of sound as given by equation (12) for a pressure midway between p_o and p, and v'' is one-half the velocity of flow as given by equation (13) for adiabatic expansion from p_o to $p = \frac{1}{2}(P + p_o)$.

Step 3.—Calculate the time $t_{11} = \frac{L-x}{c''-v''}$ where x has the value as calculated in Step 2, and c'' and v'' are as explained in the above remark.

Remark.—During the time t_{11} the pressure at the breech falls from p_1 to P, as shown in Fig. 24.

Step 4.—Calculate the impulse value of the backward force on the breech. It is equal to

$$[\tfrac{1}{2}(p_o + p_1)t_1 + \tfrac{1}{2}(p_1 + P)t_{11} - P(t_1 + t_{11})]q,$$

as may be understood from Fig. 24. This impulse value is equal to that part of the recoil momentum of the gun which is produced after the projectile leaves the muzzle.

Collodion Enamels for Leather. T. CALLAN. (*Leather World*, vi, 523.)—Collodion enamels for leather usually contain nitrocellulose; solvents, boiling-point 55° to 80° C., such as acetone, ethyl acetate, and camphor dissolved in alcohol; solvents, boiling-point 110° to 160° C., such as amyl acetate and amyl formate; diluting agents such as petroleum hydrocarbons, benzene, and methylated spirit; softening agents such as castor or linseed oils; coloring matters. Enamels prepared with low-boiling solvents only will not give a coherent film on evaporation except in a warm, dry atmosphere, as the rapid evaporation of the solvent cools the enamel, moisture is condensed from the air, and the nitrocellulose is precipitated as a white powder. The addition of a high boiling solvent reduces the rate of evaporation, thus preventing surface cooling, and gives a brilliant film. With a nitrocellulose soluble in a mixture of camphor, alcohol, and benzene of ninety per cent., these solvents can be used as cheap diluting agents. The addition of castor oil or linseed oil makes the enamel more flexible, but also softer and less durable, hence most of the oil should be in the lower coats. The coloring matters are usually pigments, but occasionally spirit-soluble dyes are employed.

Oil for Electrical Purposes. C. C. GARRARD. (*Electrician*, lxxiii, 797.)—This article gives a short account of tests which should be applied to oils used for insulation purposes in oil switches and in oil-cooled transformers. The oils generally employed at the present time are hydrocarbons, principally of the paraffin series, obtained by the distillation of the crude petroleum. Three simple tests are given to indicate the presence of moisture, which must be particularly guarded against; if necessary it may be removed by passing the oil through dried filter paper in a filter press. A more reliable method of testing for moisture is to determine the dielectric strength by finding the breakdown voltage between two spheres immersed in the oil. A simple point and plane dielectric test is also described. The value obtained should not be less than about 90,000 volts per centimetre. Tests should be applied to show the absence of acid or alkali and sulphur. The oil should not flash at less than 190° C. as determined on the Gray flash-point apparatus, when intended for use in switches, but for transformers it may be some 35 degrees lower. The viscosity of the oil is a matter of small importance in transformers, but for switch-work certain limits should be specified. A satisfactory oil would have a viscosity as determined on the Redwood viscosimeter of not more than 850 secs. at 4° C. and not less than 100 secs. at 21 ° C. Oils, particularly those for transformer use, should not show any appreciable tendency to "sludge," due to oxidation of some of the constituents of the oil.

Combustion of Coal in Boiler Furnaces. J. K. CLEMENT, J. C. W. FRAZER, and C. E. AUGUSTINE. (*U. S. Bureau of Mines*, Paper 63.)—Experiments with a furnace having an unusually long combustion chamber, from which samples of the gases could be drawn at intervals along its length, showed that with a constant rate of firing the time necessary for complete combustion of the gases, and hence the length of chamber required, decreases with an increasing air supply.

Bearing Metals. ANON. (*Amer. Mach.*, xli, No. 18, 760.)—Bearing metals or linings may be classified under two heads—babbitt metals, which are largely tin, lead, antimony, and some copper compositions, and brasses and bronzes, which are tin, copper, and zinc compositions, sometimes containing certain percentages of lead. Babbitts range in composition from a cheap metal containing 90 pounds lead and 10 pounds antimony to mixtures containing about 88 pounds tin, 4 pounds copper, and 8 pounds antimony. Babbitt metals are divided into three classes: the lead-based anti-friction metals, in which the lead content is the heaviest, the smaller percentages being tin and antimony; the semi-tin-based metals, in which the tin and lead contents are about equal, leaving room for ten to twenty per cent. antimony; and the tin-based metals, which range from 75 pounds to 90 pounds tin in each 100 pounds.

GLASSES FOR PROTECTING THE EYES FROM INFRA-RED RAYS.*

BY

W. W. COBLENTZ, Ph.D.,

Associate Physicist, U. S. Bureau of Standards.

ALTHOUGH it does not appear to be definitely settled that the infra-red rays from incandescent sources, such as molten metal, etc., are injurious to the eye, there is nevertheless considerable agitation to protect the eyes of workmen who are subjected to the intense heat coming from molten metal, and especially (for glass blowers) from furnaces containing molten glass.

Some years ago I examined [1] a series of colored glasses, but found none which had a marked absorption in the infra-red—other than the usual opacity, beyond 3.5 μ, which obtains in ordinary, visually transparent glass. Fortunately glass manufacturers are taking an active interest in this matter, and, by employing trained investigators, seem to be at the point of producing glasses which are almost entirely opaque to infra-red radiations. Their tests, which may show that a glass absorbs, say, ninety per cent. of the infra-red, do not elucidate matters very much; for much depends upon the distribution of energy in the spectrum of the source. During the past two years frequent inquiries have been made concerning the reliability of such claims, and recently, at the request of Mr. I. G. Priest, who submitted several samples of glass made by the Corning Glass Works, I made a further examination into this matter. Believing that the data obtained will be useful to the public, they are herewith presented.

Referring to Fig. 1, curve No. 1 gives the transmission through a sample of glass, 1.47 mm. in thickness, which had a yellowish-brown color, and having the maker's number, "G124, H.L., shade No. 1." Curve No. 2 gives the transmission through a much more opaque sample of the same kind of material, 2.16 mm. in thickness, and marked "G5, C.A.D., shade No. 4." It transmits about 5 per cent. in the "orange" part of the spectrum, while the former transmits almost 30 per cent. in the "orange."

These samples absorb also the violet end of the spectrum.

The most interesting sample examined had a faintly bluish tint, being quite colorless. Nevertheless the infra-red is marked

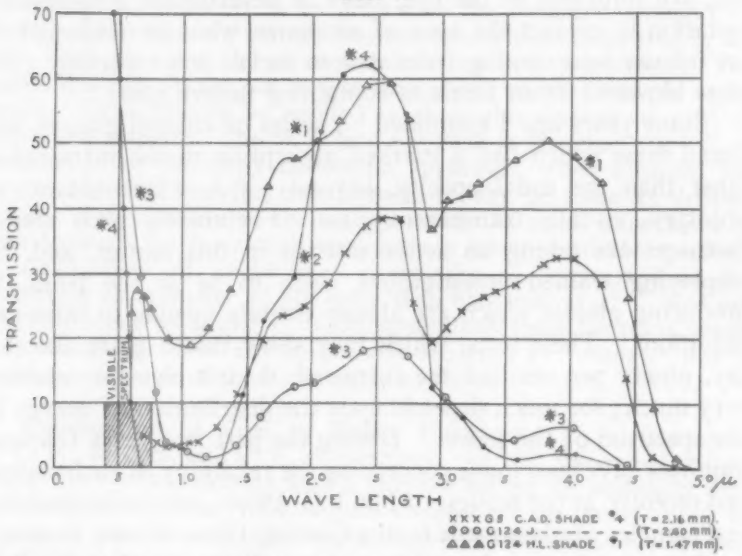
* Communicated by the Author.

[1] Publication No. 97, Carnegie Institution of Washington, 1908.

by almost complete opacity. The transmission curve is given as No. 3 in the accompanying illustration, the thickness being 2.6 mm., and the maker's number being "G124 J." This will make excellent spectacle glass for working near a "red-hot" source which emits but little light, but which emits a great deal of "heat," —*i.e.*, infra-red radiations.

Referring to the previous publication,[1] it was shown that

FIG. 1.



ordinary black glass ("smoked glass") is quite transparent in the infra-red, although it is quite useful for reducing the visible radiations. Indeed, the present sample of blue glass is the first one which the writer has found to fulfil the claim of great opacity in the infra-red. Another blue glass (Corning G401 ZA and Schott's blue-violet glass No. F3086) has practically the same form of transmission as Curve No. 3 in the infra-red. The transmission curve is given in Fig. 1, No. 4. The peculiarity of this glass is that a high transmission in the visible gives a high transmission at 2.2 μ.

It appears as though in the near future glasses fulfilling every requirement will be obtainable, and it speaks well for American enterprise to be willing to spend a few dollars in attempting to produce devices for safeguarding the health and contentment of the public.

THE BEHAVIOR OF ENZYMES AT LOW TEMPERATURES.*

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S., Ph.D.,

University Fellow in Biological Chemistry, Columbia University, 1912–1913.
Member of the Institute.

THE influence of low temperatures on enzymes is a subject of growing importance to the chemist, the biologist, and the bromatologist. Problems in this field may be studied from either the potential or the kinetic side; for either the resistance of an enzyme to, or its activity at, low temperatures may be investigated. Various researches, conducted during the last half century, have demonstrated that enzymes survive exposure to low temperatures and also act as catalysts at such temperatures. The reports of these researches are widely scattered in the literature; and frequently the original papers may be obtained for consultation only with difficulty. It is the purpose of this paper, which is based on primary sources, to give a *résumé* of our present knowledge of this subject. One section is devoted to the resistance of enzymes to low temperatures, and one to their activity at such temperatures.

THE RESISTANCE OF ENZYMES TO LOW TEMPERATURES.

The researches reviewed below demonstrate that the following enzymes survive exposure to low temperatures and again exert their usual catalytic power when brought into a suitable environment: diastase, inulinase, invertase, maltase, zymase, lipase, protease of plants, pepsin, trypsin, thrombin, rennin, oxidase, peroxidase, catalase, simple and aldehyde reductase. This order will be followed in presenting the data.

Solutions of *diastase, inulinase,* and *invertase,* after exposure for forty-five minutes to the temperature of liquid air (ap-

* Communicated by the Author. This contribution is based on a paper to be published by the writer in the *Biochemical Bulletin,* 1915, iv.

In this paper full details will be given of the researches of various investigators on the influence of low temperatures on enzymes, and a complete bibliography appended.

proximately — 191° C.), retained unaltered their power to hydrolyze starch, inulin, and sucrose respectively. The diastase was obtained from human saliva and from *Aspergillus niger;* the inulinase from that Aspergillus; and the invertase from both that Aspergillus and beer yeast.

After yeast press juice had been repeatedly cooled to — 2° C., its *maltase* retained the power to invert maltose.

Zymase in yeast press juice survives complete freezing of the juice. The enzyme may be concentrated by cooling the juice to — 2° C. and removing the ice crystals from the solution of enzyme in the mother liquor. Zymase has been prepared by trituration of a mixture of solid carbon dioxide (carbon dioxide snow)[1] and dehydrated yeast cells for a period of one-half hour. It is resistant to a temperature of — 182° to — 190° C., that of liquid air; for yeast cell plasma, held at that temperature for twenty hours, retained unchanged its power to produce alcoholic fermentation.

The *lipase* of a pig pancreas, which had been kept in cold storage at 4° C. for seven days, retained about forty per cent. of its power to hydrolyze ethyl butyrate. Lipase was found in fresh eggs which had been held at 0° C. for sixty-six days. It was present in the crude abdominal fat of a chicken kept at 0° C. for twenty-four hours after death, in that of chickens of known history held hard frozen for periods of twelve and one-half, thirteen, sixteen, twenty-eight, twenty-nine, and forty-two months at a temperature of — 9.4° to — 12.2° C., and in that of birds, whose history prior to freezing was unknown, kept at that temperature for periods of fifty-four and eighty-nine months.

The *protease of plants* survives freezing temperatures. Sprouting wheat seedlings, excoriated peas, excoriated germinating peas, etiolated caulis tops, etiolated leaves and green leaves of the bean *Vicia faba* were frozen, usually for twenty-four hours. Their proteases were still able to produce autolysis of the tissue proteins at room temperature.

Solutions of *pepsin* and *trypsin*, after exposure to the temperature of liquid air (approximately — 191° C.) for forty-five

[1] The temperature of solid carbon dioxide vaporizing at ordinary atmospheric pressure is approximately −75° C. (Richter *Inorganic Chemistry*, Fifth American Edition, p. 228.)

minutes, were practically unaltered in their ability to digest albumin.

The clotting enzymes *thrombin* and *rennin* likewise survive exposure to the temperature of liquid air. Thrombin of dog's blood held at — 180° C. for thirteen minutes retained in full its power to produce clotting of the blood.

Commercial rennet, kept at — 180° C. for periods of one, five, ten, and thirty minutes, was entirely unchanged in its action on milk at 35° C. In another experiment a rennin solution, which was kept in boiling liquid air for over one hour, retained completely its power to produce clotting of milk.

Oxidase was present in milk held at 0° C. for as long as thirty-five days, and in cream held at that temperature for as long as twenty-eight days. Both milk and cream were rendered bacteriologically sterile by addition of 0.1 per cent. of formaldehyde before storage.

Both oxidase and *peroxidase* were found in the crude fat of a chicken kept at 0° C. for fifteen days after death, and in that of hard-frozen chickens, including birds of known history, kept in the freezer for nine months and birds, whose history prior to freezing was unknown, held in the freezer for periods of twenty-three and sixty-three months; the temperature of holding was — 9.4 to 12.2° C.

Catalase has been found in milk and cream rendered sterile by addition of 0.1 per cent. of formaldehyde and held at 0° C. for twenty-one days. It has also been detected in eggs, including both the white and the yolk, after the eggs had been kept at 0° C. for sixty-five days.

Catalase has also been demonstrated in the crude fat of chickens of known history held hard-frozen for nine months at a temperature of — 9.4 to — 12.2° C., in sole kept frozen for nineteen to twenty-one days at — 2° to — 9.5° C., and in cod kept frozen for thirty days at — 2° to — 6.5° C.

Simple reductase has been found in formolized, sterile milk and cream kept at 0° C. for twenty-eight days; the cream also contained *aldehyde reductase*.

Simple reductase occurred in the crude fat of chickens of known history held hard-frozen for nine months, and in that of chickens, whose history prior to freezing was unknown, kept in the freezer for twenty-three months. Aldehyde reductase was

present in the birds of the latter class after periods of twenty-three and sixty-three months in the freezer. The temperature of holding was — 9.4° to — 12.2° C.

THE ACTIVITY OF ENZYMES AT LOW TEMPERATURES.

Studies have been made of the activity of the following enzymes at low temperatures: invertase, maltase, zymase, diastase, lipase, pepsin, trypsin, galactase, urease, rennin. This order will be followed in presenting the data. At times the enzyme studied was permitted to produce an autolysis, at times to act in solution on an artificial medium, at a given low temperature.

Invertase, maltase, and *zymase* are active at the temperature of an ice-box, for yeast press juice ferments saccharose, maltose, glucose, and fructose at that temperature.

The *diastase* of carp liver acts on starch at 0° C., converting it first into soluble starch, then into erythrodextrin, and finally destroying the latter compound.

The *lipase* of pig pancreas has been shown to hydrolyze ethyl butyrate at 0° C., and to hydrolyze neutral lard at — 9° to — 12° C. The lipase of pig liver splits ethyl butyrate at 0° C. and at — 10° C. The lipase of crude chicken fat produces hydrolysis of ethyl acetate, butyrate, and benzoate and amyl salicylate at 0° C. and at a temperature of — 6.7° to — 9.4° C.

Pepsin.—The gastric protease of the frog, the pike, and the trout digests albumin at 0° C.; that of the frog also digests fibrin at 0° C., while that of the pike produces proteolysis of fibrin at temperatures as low as 0° C. Pepsin of pig's stomach converts coagulated ovalbumin into acid albumin, albumoses, and peptones at 0° C. Pepsin also digests ricin at that temperature.

Trypsin, derived from the intestinal tract of the carp, gave rise to proteolysis of gelatin and of fibrin at 0° C.

Galactase, the trypsin-like enzyme of milk, gives rise to a proteolysis in Cheddar cheese which is ripened at 15° F. (— 9° C.), 25° to 30° F. (— 1° to — 4° C.), and 33° F. (+ 0.6° C.). Galactase also produces proteolysis in milk rendered sterile by addition of 0.1 per cent. of formaldehyde and held at 0° C. The digestion of the proteins observed in milk kept at — 9° C. has been ascribed to the action of galactase.

Urease of the soy bean hydrolyzed urea at temperatures as low as 0° C.

When *rennin* acts on milk it first transforms the casein into paracasein and then precipitates the latter compound as a coagulum. The first stage of the reaction occurs at 0° C.; the second stage likewise takes place at that temperature, but the precipitate separates in a finely-divided condition without the formation of a distinct curd.

SUMMARY.

The power to survive prolonged exposure to low temperatures is possessed by various enzymes, including those producing hydrolysis of fats, of carbohydrates, and of proteins, those concerned in biochemical oxidations and reductions, the clotting enzymes and that of alcoholic fermentation. The enzymes retained their catalytic power after exposure, either *in situ* or in solution *in vitro*, to temperatures varying from a few degrees above 0° C. to the temperature of liquid air (−180° to −191° C.). The shortest periods of holding, invariably less than one day and usually less than one hour, were at the temperature of liquid air. The longest period of holding was eighty-nine months at a temperature of −9.4° to −12.2° C.

The activity of certain of these enzymes, including rennin, zymase, and those hydrolyzing fats, carbohydrates, and proteins, has been studied at low temperatures, varying from that of an ice-box to one of −9° to −12° C. While the enzymes produced autolytic digestion or acted on artificial media at these temperatures, the velocity of the reaction was always lessened to a considerable degree.

Electric Tanning. O. J. WILLIAMS. (*Collegium*, dxv, 76–78.)—Electric tanning not having been successful, the author investigates in this preliminary note whether the electric current destroys the tannic acid as observed by Nierenstein. Electrolyzing pure tannic acid (five per cent. aqueous solution) 15° C. between carbon plates with continuous currents of 0.004 amp./cm.^{2} he finds that the optical activity (Nierenstein's method) of the solution is rapidly diminished. In other experiments in which platinum electrodes and currents of up to 0.075 amp./cm.^{2} continuous or 93 periods per second were used, the alternating currents did not destroy the tannin whilst favoring the electric endosmose, in accordance with F. Rolver. The electromotive force applied is not stated.

Electrolytic Iron. L. GUILLET. (*Iron and Steel Institute J.*, xc, 66.)—Since 1910 the Company Le Fer, of Grenoble, has manufactured electrolytic iron by using a revolving kathode in an electrolyte of neutral iron salts. The bath is circulated, and oxide is added periodically to act as a depolarizer. Using pig iron containing 2.35 C, 1.31 Si, 0.07 S, and 1.07 per cent. P, it is possible to obtain a product having the following analysis after annealing: C, 0.004; Si, 0.007; S, 0.006, and P, 0.008 per cent. The crude material is hard and brittle, showing a ball hardness of 193. Annealing commences at about 300°, but it is not complete until heated at 900° C. for some time; the material then has a hardness of 90. Determination of the values of the physical properties of the annealed metal gives results which agree closely with those previously published. With regard to the industrial applications of the material, it can readily be deposited in the form of tubes and sheets. On account of their high degree of purity the sheets are specially adaptable to the construction of electrical machinery. Their favorable values as regards hysteresis and permeability render it possible to effect considerable economies in the weight of transformers and direct-current machines, and to increase the capacity of alternating-current motors. As a raw material for fusion electrolytic iron will undoubtedly be able to enter into direct competition with Swedish iron, over which it possesses the advantages of being more uniform in quality and more readily broken into pieces of any desired size. The cost of production varies from £5 to £7 12s. per ton, according to the local conditions.

Zinc as a Boiler Compound. ANON. (*Metal Industry*, xiii, No. 2, 56.)—A recent order placed in this country for export of 400,000 pounds of zinc calls attention to one of the uses to which this metal has been applied abroad, which perhaps is not widely known in the United States. The order referred to above was for pure zinc in the form of plates six inches long, four inches broad, and a half inch thick. These plates had a half-inch hole bored or punched through the centre, and the method of using them is as follows: A steel rod is introduced through the side of a boiler, and these plates of zinc, together with steel or iron washers, are strung on the rod in alternate layers, so that there is constant contact between the zinc and the iron all the way across the boiler. When the boiler is in use this arrangement of the two metals constitutes an electric couple, and a galvanic current of electricity is set up inside the boiler which, it is claimed, effectively prevents not only foaming of the boiler, but also the deposition of scale. In this way the use of various materials known as " boiler compounds " is eliminated and the boiler is kept in good, clean condition for an indefinite period. There does not seem to be any reason why aluminum plates used in the same way will not produce the same results, and possibly, owing to the difference in specific gravity between aluminum and zinc, more surface may be offered for action by using aluminum.

ADDRESS TO GRADUATING CLASS, FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.*

BY

GEORGE A. HOADLEY, Sc.D.,

Emeritus Professor of Physics, Swarthmore College.
Member of the Institute.

No MAN who is in mental health ever completes his education. His condition of bodily vigor has a decided effect upon it, but nothing short of a mental breakdown or death puts an end to his acquirement of what we call an education.

There are many phases to this lifelong process, and it is a good plan for us to stop for a little, whenever we reach the end of a certain phase or part of the work, and take a look back over the path along which we have come, and forward into the undefined future, in order that we may learn the lessons that the past teaches and get a firm grasp of the hopes that the future holds out to us.

You of the graduating class of The Franklin Institute have reached the end of one of these phases in your education to-night, and it is fitting that we should consider, for a time, what education may mean.

While we are surrounded, from our earliest conscious existence, with persons and things that are our teachers, I believe that we must agree with many of the wisest men of the past and the most experienced men of the present that what we get out of our education we shall have to put into it ourselves.

This may seem to be a contradictory statement, or one that suggests an impossible condition, but it is not when once it is understood.

To put energy, enthusiasm, and perseverance into the study of any subject brings to the student a thorough comprehension of that subject and also the ability to apply its principles to the demands of the practical in everyday life. It also gives him such a grasp of the fundamentals of the subject that he can meet the unexpected demands that are sure to arise, and at the

* Delivered at closing exercises of Ninety-first Year of School, April 16, 1915.

same time it enables him to find the solution for new problems that marks him as a successful man among his fellows.

If, on the other hand, a man undertakes his study in a half-hearted kind of way, if he takes it up as a pastime rather than as a pursuit of real importance, he will find that the knowledge he has gained on the subject is only superficial, and his ability to apply what he has learned will be so small that it will prove of little value to him or to any one else.

I am taking it for granted that the object of an education is that a man may be of greater value to himself and to his fellowmen.

I very well know that there is an education that a man can give himself that adds greatly to his ability to read and understand what others have written and to grasp the details of the inventions that others may have made. This kind of education is by no means to be despised. It adds much to the value of life for any man, and makes him more a part of the times in which he lives.

But the kind of education that The Franklin Institute believes in, is that which not only enables him to be an intelligent reader of history, but to become a helper in the making of the history of his own time; that enables him not only to understand the principles that underlie any invention, but that gives him the power to apply principles already known, in new directions, and thus to become an inventor himself; that enables him not merely to absorb what is already known for his own improvement and use, but to digest what he absorbs and to put it forth in a new dress, thus giving to the world something new in Literature, in Art, or in Science.

There is one term that is frequently used, and that is generally applied to a man who has been what is called successful in life, and that is the term "Self-made." People say of such a one, "He is a self-made man," as though that set him off in a class by himself. This is never said, as it should be as well, of one who is not a success, while it is the only thing to say of any one, for the truth is that there are no other men living except self-made men.

The very fact that the term is never used except to point out those who are successful in their endeavors is both an acknowledgment of that success and a testimony to the importance of

selecting the right things upon which to expend one's energy.

The longer I live the more I am convinced that a young man who determines to secure success in life in any definite direction can secure that success, provided always that he is willing to pay the price of whole-hearted devotion, untiring energy, and a resolute putting aside of anything that does not help in securing the desired end.

If a man determines to secure wealth, he will make that his main purpose in life. If he is in haste to be rich, he will very likely risk his savings in ventures that promise with a lavish prodigality, but when it comes to the returns will probably produce nothing but loss and thus make shipwreck of his purpose. If, however, he is willing to take the sure but slow path that leads to wealth, he will lay aside each year whatever he can compel himself to save from his earnings, and will add to this sum the increase which it will bring if invested in some perfectly safe way, and he will find himself, as the years go by, with a bank account that gains from year to year with increasing rapidity.

Suppose, to take a concrete example, that a young man of twenty saves twenty-five cents per day for each working day. This makes one dollar and fifty cents per week, or seventy-eight dollars per year. Now by investing this money at five per cent. and also investing the interest each year until he is fifty years of age he will find at that time that he has saved $4819.36, while if he continues the practice until he is sixty years of age he will find himself the possessor of $8900 in cash, an amount that will provide for his ordinary expenses for the rest of his natural life if used with a reasonable amount of economy.

If this saving of twenty-five cents per day seems to be too much, let us assume that he can save five cents per day, the cost of a car fare, and at fifty years of age he will have over a thousand dollars.

These examples of what persistent saving will accomplish are not given for the purpose of magnifying the importance of saving money, but with the idea of calling attention to the fact that persistence in an undertaking is one of the most important factors in attaining success.

I have said that if a man makes up his mind to attain a certain end and is willing to pay the price he can be sure that he will succeed, and have shown how this will work out in the

saving of money. The same statement is true whatever may be the end sought.

Suppose that a young man determines that he will make himself a master machinist. This means more than to become an expert workman, though it includes that as a part of the training. It means not only that he must know how to operate every kind of machine that is to be found in a well-equipped shop, but he must know how to do this with the greatest economy, and he must also know how to get out of the machine a maximum output for the power it absorbs.

He must understand the construction of the machine, study the mechanical principles through which it operates, be quick to see how it can be improved, and be able to put these improvements into practical shape. In short, he must make machines his study, and when the demand for a new form of product is brought to his attention he should be able to devise, build, and operate a new machine that will put the product on the market.

If a man determines to become a salesman, and not only that, but to become one of the best, a man who will always command a good position and salary, he will need to know much more than the story of the goods he sells. He will need to know *that*, from the smallest detail of manufacture to the various prices at which they can be put upon the market, but he will also need to know *men*, and this is his greatest need. He will probably have to put more time into a study of the men to whom he hopes to sell his goods than into a study of the goods themselves.

In this study he will require all his experience and an intimate knowledge of psychology to enable him to recognize the varying moods of his customers and to adapt himself to these uncertain moods.

The particular thing that I am trying to bring to your attention is that persistent and determined effort is the one thing that is sure to bring success, and I will cite a single authentic example.

About forty-five years ago a boy working for a neighbor at cutting and shocking corn had the good fortune to find a seedling peach tree in the fence corner on one side of the field that was filled with small but toothsome peaches. Every time that his work brought him to this side of the lot he took a seat upon the fence to rest and while doing so would eat a few of these delicious fruits. Not only did he eat the peaches, but he thought

about how it had happened that the fruit of this seedling was so much sweeter and better flavored than any peach he had tasted before. He also began to suspect that the seedling tree grown from the kernel in a peach stone would not produce a peach like the one from which it came, but that it would have a flavor all its own.

He then began to wonder if it would be possible to plant a great many peach stones and finally get a peach much bigger and finer flavored than any other. Then came the resolution to coax his mother to let him have some land and to follow up this idea as best he could.

The decision changed the lonesome boy in the cornfield into a potential fruit raiser, and when he got down from the fence and went to work again he put into it the zest that comes to one who is working out a new plan.

The next year, in 1869, the boy got a better job, one that paid him $12.50 per month and his board, and out of this he saved enough to buy and set out two hundred of the best peach trees he could find.

From this time on the boy devoted his entire time to the raising of fruit, mainly peaches, and during the year ending August 1, 1912, he raised and sold over 100,000 bushels of the finest peaches in the market.

One afternoon, fifteen years ago, this man, who had spent thirty years in studying this one fruit, drove through an orchard of early peaches that had been picked and sent to market weeks before. In this orchard he noticed a seedling tree that was full of beautiful big, red peaches, and on trying one of them he found it to be a delightfully flavored freestone and that what he had been looking for for thirty years had come to him, and since that time he has devoted himself to the propagation of this magnificent peach. This man is raising and selling these trees just as enthusiastically to-day as ever, and so contagious is his enthusiasm and so great is the benefit he is conferring upon mankind by the propagation of this tree that they are being set out and cultivated by the million.

Thirty years seems to be a long time to wait for success, but when it comes in such unquestioned form and receives such cordial recognition it is well worth the waiting for.

When a young man graduates from an institution he is not usually in a position to be his own employer. As a general

thing he is looking for a job, or, if you prefer it, he is trying to find a position.

I must confess I like the first way of putting it best. It has in it more of a feeling that the man who is looking for a job wants to do something, and there are very few employers who are willing to pay a man for his mere presence at the plant.

I have a feeling that no man has a right to take a position solely for the money there is in it. If he does, it is an indication that he is simply selling his time, that he is not putting himself and his interest into his work.

Suppose that you imagine yourself to be the employer. Suppose that you had spent years in developing a business and depended in a great measure upon the loyalty and interest of those in your employ to carry it on and develop it as your experience has taught you it can be developed.

Imagine the anxiety with which you would look into the face of a young man who came to you for employment, and how certainly your decision as to taking him would be determined by the impression you formed of his ability and interest, and his remaining in your employ would depend upon how well his work had carried out the opinion you had formed in that short interview.

One of the most important things in the industrial and business world to-day is the relation between the employer and the employed. Their interests should be identical and the coöperation between them should be of the most cordial type.

It is very certain that if there were no employers there would be no employment to be obtained, and no manufacturer could carry on his business without the assistance of the men who work for him.

There would be no question of this cordial coöperation if both the employer and the employed would each consider himself for a short time in the position of the other and honestly consider what he would think best to do when in that position.

The employer needs to feel the difficulty the workman finds in meeting the demands made upon him in giving his children the education that is the best legacy that he can leave them, and in furnishing for his family the comforts that mean so much in our everyday life.

The workman needs to feel the responsibility that is always

with the employer to provide work for his men, to be able to meet the gripping competition under which he is always working, and the sleepless nights that he passes in trying to see how he can make enough in the business to pay his men, meet his interest, and save enough out of the returns to allow him to give his family reasonable comforts.

No man can be of the greatest use to his employer who does not take an interest in his work and who is not faithful to the trust that is imposed in him.

I know a man who for some years was in sole charge of a small gas plant, a plant that required but a single man for the greater part of the time. After a while his employers decided that they would stop the manufacture of gas for themselves and buy their supply from a large company in the neighborhood. It was arranged that my friend should go with the larger company as day watchman in charge of the grounds. He easily proved himself qualified for the place, and when the head of the company rode into the grounds one day in his automobile and proceeded to make an inspection of the plant he was held up by the watchman, who asked him what he wanted. "What do I want? Why, I am the head of the company and am looking things over."

"Do you have a permit with you?" "No, I don't need one." "Well, I don't know you, and you can't stay here without one," and the watchman drove him out of the grounds.

Now this was an experience that had never come to the employer before, but he saw that if this could happen to one who claimed to be the head of the concern, and came in the proper style for a man in that position, it would be liable to happen in the case of any one who might want to come into the grounds for improper purposes, and that watchman is now one of their most trusted employees.

Loyalty to the men who employ him and a living interest in the business in which they are engaged are qualities that are highly prized by any employer, and form a most valuable asset for the man who is looking for work.

There is no type of service that a man can render to his employer in which loyalty is not of value. I was talking the other day with one of my neighbors, a graduate of a college, who has for years held a position of large responsibility with one of the most successful business concerns of this city. In the course of

the conversation he remarked that his business now took him away from home a great deal. On inquiry I found that his company had decided that it was necessary to have a representative in New York and he had been selected for the position.

Now, while this transfer is a recognition of his faithfulness and loyalty, it brings with it the discomfort of taking him away from his family and from a most comfortable home. In speaking of this he said: "Yes, it is not convenient, but when you are working for an employer you must do as he says." I believe it is this recognition of the rights and interests of his employers that has made him of so great value to them.

There can be no doubt that some of you will eventually become employers, and at that time, if not before, you will recognize the value of having the coöperation of your employees in your business.

We hear a great deal in these days about efficiency and it has come to have a restricted and harmful meaning.

I have the greatest respect for the efficiency that succeeds in getting from both men and machines the greatest output that can be obtained, provided the welfare of both is considered, but I have none whatever for a so-called efficiency that extracts the maximum output from a man at the cost of turning him into a piece of automatic machinery.

There is a greater product that can be turned out by a manufactory than the product of its machines, and that is the manhood of those who run them. That business is not worthy of support that succeeds financially at the expense of either the physical, mental, moral, or spiritual welfare of its workmen.

I have said that you who graduate from the schools of this Institute have now reached the end of one phase of your education. This, however, is a phase of your education and not the whole of it. It is unquestionably a fact that what you have learned here has made it more possible for you to carry on that education either by yourselves or with the aid of other schools and colleges.

The education that we give you here we try to make practical. A good share of what you have learned you will make immediately available, some of it you will not, and perhaps you will think it of little value, but I will venture to say that you will, at some time or other, find use for everything you have learned.

It is a striking commentary on the value of an education, that so few uneducated men ever attain prominence in the things of highest value. Those who have taken advantage of the best educational opportunities are directing the destinies of the nation.

This is shown by the fact that a very large percentage of the Judges of the Supreme Court, Senators, Representatives, and Governors of States are college graduates, while those who are not have won their positions through the service they have rendered their fellow-men while educating themselves in the college of experience.

Education is something you must get by hard work. It is something you cannot buy. You can give it away to no man, and no man can take it from you. It extends the boundaries of your mental vision, and it gives you the key with which to unlock the treasure-house of all time. To gain it, men have starved their bodies and through it they have beautified their souls. It is among the best of the gifts of the Creator, since it is a prize that any one can win.

"Natural" Electrolytic Corrosion in Soils. E. H. SCHOFIELD and L. A. STENGER. (*Elect. Rly. Journal*, xliv, 1092.)—This is a record of some laboratory experiments which are intended to prove that electrolytic corrosion of metallic structures takes place under certain conditions naturally, and is not dependent entirely on stray traction currents. There are two classes of cases which are considered. First, there is a case where a metal such as cast iron or steel contains impurities in its structure, and, secondly, there is the case of the metal, like lead, which is ordinarily considered non-corrodible, but which is none the less liable to corrosion if in contact with two soils of different compositions,—*i.e.*, containing two different electrolytes. These two cases were studied experimentally, a large number of soils being collected for the purpose of the tests, and in both cases it was established that corrosion, undoubtedly of an electrolytic nature, was set up, owing to the natural action of the soil, and quite apart from any effect which could be due to stray currents. Cast-iron samples, where corroded, were covered with a hard scale of rust and soil; the pits in the cast iron were local, and filled with carbon and black iron oxide. The lead samples showed the presence of both the gray and the brown oxides. Potential differences up to one volt were generated by placing different metals in contact with certain soils, or by placing two pieces of similar metal in contact with different soils. Photographs are also given of cast-iron and mild steel pipes, which have been pitted electrolytically in districts where no electric railways or leakage currents exist.

Semi-portable Superheated-steam Engine. (*Engineering*, xcviii, 560.)—This illustrated article describes a 100-b.h.p. "locomobile" type of engine constructed by Marshall & Co., Gainsborough. The side-by-side compound engine is mounted on the boiler top. The cylinders are in one casting with separate liners. Steam is distributed by balanced piston-valves with special spring rings driven from the crank shaft by eccentrics and rocking levers. Governing is by cut-off variation in the high-pressure cylinder. The exhaust steam passes through a tubular feed-heater to a jet condenser. The Cornish multitubular boiler is made of Siemens-Martin steel for working at 180 pounds per square inch pressure. The firebox and tubes can be removed bodily for internal examination, etc. A recent four-hour test gave the following results: Feed temperature, 120° F.; steam pressure, 188.7 pounds per square inch; steam temperature, 541° F.; superheat, 158° F.; vacuum, 27 inches; r.p.m., 206; b.h.p., 124; coal consumption, 1.47 pounds per b.h.p.-hour; calorific value of coal, 11,500 B.T.U.s; coal burnt per square foot grate area, 23.7 pounds per hour; CO_2 in flue gases, 10.9 per cent. Similar plants are made for capacities of 50 to 300 b.h.p. The special superheater is described in detail.

A New Primary Cell. E. BELLINI. (*Lumière Electr.*, xxvi, 115.)—The author draws attention to the fact that in the usual types of cell employing zinc a soluble salt forms and the zinc is liable to be deposited on the electronegative plate, thus polarizing it. He therefore sought to design a cell in which the salt formed would be insoluble. The objection to doing so is that the insoluble salt may remain upon the plate, thus increasing the internal resistance during the life of the cell. The author selected lead as his electropositive metal, and had, in order to eliminate the last-mentioned difficulty, to use it in the form of an amalgam. This he forms by adding ten per cent. of mercury to the molten lead. Carbon is used as the other plate, and the electrotype consists of the following mixture of sulphuric and nitric acids: Water, 1000 c.cm.; sulphuric acid of 66° Baumé, 80 c.cm.; nitric acid of 36° Baumé, 120 c.cm. The electromotive force is 1.25 volts. Curves are given showing the discharge obtained. In the case of a cell containing 2.6 litres of electrolyte a current varying from about 4.5 ampères down to 4 ampères was obtained during 13½ hours, and was more or less repeated after a rest of 11 hours. A further discharge of 14 hours with rather higher current was then obtained by adding a certain quantity of the mixed acids.

Uranium Ores in Madagascar. C. GROSSMANN. (*Comptes Rendus*, clix, 777.)—A mineral has been discovered at Fiadanana, Madagascar, externally resembling euxenite and containing twelve to forty per cent. U_3O_8. Its radio-activity, tested by an aluminum foil electroscope, is about double that of the pure oxide, thus suggesting an important source of radium.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE VALUE OF THE HIGH-PRESSURE STEAM TEST OF PORTLAND CEMENT.†

By R. J. Wig and H. A. Davis.

THE use of high-pressure steam as a means of determining the soundness and cementing quality of Portland cement was advocated as early as 1880 by both Michaelis and Erdmenger. It has been recommended and used by others from time to time until recently, when a form of this test was advocated and introduced into specifications for the purchase of Portland cement as the Force autoclave test. Many brands of American cement would not regularly meet the requirements of this test, and its recent introduction led to a controversy between cement manufacturers and consumers. The manufacturers of Portland cement contended that this test was an abnormal one, and the behavior of a cement when so exposed was no criterion of its ultimate behavior as normally used in concrete. Furthermore, it was suggested that this test be introduced into the United States Government specification for Portland cement, and it was for these reasons that an investigation of the value of the high-pressure steam test was undertaken.

This investigation included a study of the physical properties of cements that were sound after exposure in high-pressure steam and cements that failed to meet the requirements of this test. Tests were made of the tensile and compressive strength in mortars, compressive strength in concretes, and the linear change of neat cement prisms stored in air, in water, and treated in high-pressure steam.

The qualitative high-pressure steam test consisted of subjecting a pat of neat cement, after storing for the first twenty-four hours in a damp closet, to steam at a pressure of 300 pounds per square inch for one hour, in a steam-tight boiler, the total time in the boiler being three hours. A cement was said to have passed

* Communicated by the Bureau.

† Abstract of Technologic Paper No. 47.

this test if the pat was hard and sound when examined after this treatment. The quantitative high-pressure steam test consisted of moulding six neat cement briquettes, storing them twenty-four hours in a damp closet, then treating three of them in steam at 300 pounds pressure for one hour in a steam-tight boiler, the total time in the boiler being three hours. The six briquettes were then broken in a cement testing machine, and a cement was said to pass the high-pressure steam test if the treated briquettes showed higher tensile strength than the untreated.

Eighteen two-barrel samples of cement, composed of seven different brands, were obtained for testing in concrete. The cement of some of these samples passed the high-pressure steam test, and the cement of other samples did not. The concretes prepared from these cements have been normally exposed to the atmosphere for two years or more and tested for compressive strength from time to time. Sufficient specimens were prepared to continue the tests for ten years.

The following is a brief summary of the results of this investigation:

The general soundness tests show that some cements mixed neat which are sound according to the standard atmospheric steam test but unsound in high-pressure steam exhibit signs of unsoundness when stored under normal conditions in dry air. This unsoundness may require nine months or more to develop in neat cement specimens.

The strength tests of mortars and concretes fail to show any difference in the cementing quality of cements that pass the high-pressure steam test and those that fail to meet the requirements of this test.

There is but small difference, if any, in the linear change of prisms made of cement that passes the high-pressure steam test and prisms made of cement that fails to meet the requirements of this test, whether stored in air or water.

Seventy per cent. of a total number of fifty-one brands of Portland cement tested passed the high-pressure steam test.

Cements normally unsound in the atmospheric or high-pressure steam tests will generally be found to be more sound than the original cement if the coarser particles are removed. While fineness is not essential to soundness it appears usually to be the coarse particles of a normally unsound cement that cause

the expansive action resulting in cracking and disintegration of the hardened cement in the accelerated tests of soundness.

A cement originally unsound in the high-pressure steam test will usually be found sound if exposed to this test after aging from two to six months.

The following conclusions are drawn from the results obtained:

1. The high-pressure steam test should be made on all cements that are to be incorporated in cement mortar or concrete products that are to be cured in steam at pressures above atmospheric.

2. The high-pressure steam test may be of value as forecasting the behavior of neat cement or a very rich mortar when exposed under normal conditions in dry air, but it does not forecast the behavior of cements in concrete as normally exposed.

3. Cement passing the high-pressure steam test is not superior in cementing quality, as determined from the compressive strength of concretes, to cement that fails in this test.

4. Cement passing the high-pressure steam test does not make more permanent or durable concrete than cement which meets the requirements of the standard specifications but fails in this test.

5. Cement failing to pass the standard specification atmospheric steam test, but meeting the other requirements of the standard specifications, shows in some instances a normal strength in concrete.

6. For practical work under normal conditions of construction, the results of this investigation fail to show that the high-pressure steam test is of value as a means of determining the ultimate soundness of concrete.

THE EMISSIVITY OF METALS AND OXIDES. IV.—IRON OXIDE.

By George K. Burgess and Paul D. Foote.

[ABSTRACT]

THIS paper is a continuation of the study of the radiometric properties of metals and oxides. By the use of radiation pyrometers and the method of miscroscopic melts described in the earlier papers, the total and monochromatic emissivity ($\lambda = 0.65\ \mu$)

of iron oxide formed by heating iron in air has been determined at high temperatures.

Iron oxide in the spectral region $\lambda = 0.65\ \mu$ is almost "black," having an emissivity varying from 0.98 to 0.92 in the range 800 to 1200° C. The corrections necessary to apply to the readings of an optical pyrometer in this temperature range vary from 0 to 10° C. The total emissivity of iron oxide increases from 0.85 at 500° C. to 0.89 at 1200° C. The corrections necessary to apply to the readings of a radiation pyrometer in this temperature range vary from 30 to 50° C.

The temperature of the outside of the oxide layer is considerably different from that of the inside in contact with the metal, on account of, in part, the low thermal conductivity of the oxide and in part, undoubtedly, the actual separation of the outside oxide layer from the metal, thus forming an air gap between the two surfaces or between two surfaces of oxide, the outer one thick and the inner one thin. The drop in temperature through the oxide layer is approximately constant for various-sized samples, from small iron tubes to 100-pound rails, and increases rapidly with temperature, rising to about 100° at an outside temperature of 1100° C.

Cementing Value of Bituminous Binders. L. KIRSCHBRAUN. (*J. Ind. Eng. Chem.*, vi, 976.)—The cementing value of a binder is directly proportional to the work done in producing fracture or failure of a given unit of material. An apparatus is described by means of which strain is applied to a briquette of the material by a dynamometer travelling at a uniform speed, and the strain and elongation are measured. The briquette is drawn out until finally it either breaks or the rate of elongation becomes higher than the rate of travel of the dynamometer, so that the values recorded by the latter pass through a maximum and then return to zero. Results obtained by this method with different materials are given in tables and diagrams. The cementing value is represented by the area enclosed by a curve plotted with amounts of elongation as abscissæ and the values for the strain as ordinates; but the values for the elongation and the maximum strain must also be taken into account separately in estimating the value of a given material. In the case of bitumen for sheet asphalt pavement, it is recommended that when tested by the author's method the minimum cementing value should be 0.08 kilogramme-metre for light and 0.24 kilogramme-metre for heavy traffic, with elongations of 8 to 14 cm. and 4 to 6 cm. respectively.

THE FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, April 21, 1915.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 21, 1915.

PRESIDENT WALTON CLARK *in the Chair.*

Additions to membership since last report, 6.

Mr. George H. Clamer, Chairman of the Committee on Science and the Arts, reported the condition of the committee's work.

Mr. W. S. Bartholomew, President, Locomotive Stoker Company, Schenectady, N. Y., presented a communication on "Mechanical Stoking of Locomotives." The speaker described various types of stokers, and particularly those which are now being used. The economic value of the mechanical stoker and its effect upon the labor problem were considered, as well as the benefits received by the railroad company, especially in the elimination of the physical limit set by the firemen upon the capacity of a large locomotive, which, when mechanically fired, can evaporate all of the water the injectors are able to deliver to its boiler. The effect of the use of mechanically-fired locomotives upon the movement of traffic under present operating conditions was also shown. The subject was illustrated by numerous lantern slides.

In the discussion which followed the reading of the paper, Messrs. George R. Henderson, of Philadelphia; A. L. Willsie, of Chicago; W. L. Robinson, of Baltimore; Dr. Angus Sinclair, of New York, and others participated. After a vote of thanks to the speaker the meeting adjourned.

R. B. OWENS,
Secretary.

THE FRANKLIN INSTITUTE SCHOOL OF MECHANIC ARTS.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1914–1915.

COURSES OF INSTRUCTION.

The courses given in the ninety-first year of the School, ended April 8, 1915, were substantially the same as those given in the preceding year. Classes were formed in all the courses offered and announced in the prospectus issued last summer, and in some of the courses, notably first-year Mechanical Drawing and Mathematics, the classes were large. The courses given were: Mechanical Drawing; Architectural Drawing and Design; Freehand Drawing

and Water Color; Algebra; Mensuration and Elementary Geometry; Advanced Geometry; Plane Trigonometry; Applied Mechanics and Strength of Materials; Elements of Mechanics and Machine Design; Steam Generation; Structural Design; Theoretical Naval Architecture; Practical Naval Architecture.

REGISTRATION.

The total registration in all Departments was two hundred and sixty-seven. This was lower than that of last year. From the number of requests at the beginning of the term from students for registration with deferred payment of fees on account of loss of positions and other causes it was evident that the decrease in registration was due to the then prevailing industrial conditions.

FACULTY.

Prof. William E. Bullock again officiated as Assistant Director. Prof. Clement Remington continued his charge of the classes in Architectural and Freehand Drawing. Messrs. F. H. Lobb, I. P. Pedrick, and Charles Rommel instructed in Mechanical Drawing, as last year. Mr. W. W. Twining assisted in the Department of Drawing. Prof. Simeon van T. Jester was appointed to take charge of the Department of Mathematics, in place of Prof. H. P. Tyson, who was unfortunately obliged to relinquish this work this year on account of the pressure of other work, and Mr. H. S. Detwiler assisted him. Prof. Elmer Bark continued as Professor of Mechanics, and Mr. M. M. Mark instructed in Steam and Structural Design. Prof. H. C. Towle continued in charge of the classes in Naval Architecture.

SCHOLARSHIPS.

In August, 1914, Hon. G. W. Edmonds, member of the Institute, offered to pay the tuition fees of five new scholars as an inducement to young men to enter the School. His offer was accepted by the Committee on Instruction, and an examination of young men was held and George L. Dreeman, Fred E. Miick, Joseph H. Ritchie, Wm. H. Stewart, and Geo. W. Williams were selected and are now receiving their two-year courses by Mr. Edmonds's courtesy.

In addition to these Scholarships, there were available twelve Bartol Scholarships in Drawing from the income of the B. H. Bartol Fund, and one Thorn Scholarship in each of the Departments of Mathematics, Mechanics and Naval Architecture from the Isaac B. Thorn Fund.

PRIZES.

Mr. Samuel M. Vauclain, Vice-President of the Baldwin Locomotive Works, presented a prize to be awarded to the student of best record in the Department of Mechanics, and Mr. W. D. Baldwin, President, The Otis Elevator Company, New York, N. Y., donated a prize for the student in the Department of Drawing making the best set of drawings for the year. Mr. J. B. McCall, President, Philadelphia Electric Company, and Mr. Wilfred Lewis, President, The Tabor Manufacturing Company, again donated prizes,

as last year, as did the New York Shipbuilding Company. The Alumni Association continued its special prizes for students in Mechanical Drawing, Architectural Drawing, Freehand Drawing, Mathematics, Mechanics and Naval Architecture.

ATTENDANCE AND PROGRESS.

The attendance throughout the year was well above the average, and the work done was of exceptional merit in a large number of individual cases.

VISITS.

Six visits to places of engineering interest were paid on Saturday afternoons during the season, as follows: Milbourne Mills, Otto Gas Engine Works, The Curtis Publishing Company, Philadelphia Rapid Transit Company's Beach Power House, Link-Belt Company, University of Pennsylvania, Queen Lane Pumping Station, Bureau of Water. The average attendance at these visits was thirty.

HONORS.

Certificates for the satisfactory completion of a two-year course in one of the four Departments of Drawing, Mathematics, Mechanics, and Naval Architecture are this year awarded to sixty-one students, an increase of sixteen over last year. The names of graduates for the season 1914–1915 are appended, as also are the names of those students to whom are awarded the scholarships and prizes indicated above, and of those granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

I desire to express my appreciation of the sustained coöperation of those members of the faculty who continued in the School from the previous year, and also of the very efficient work of the new members, and I sincerely hope that when the ninety-second year opens in September, 1915, they will all resume their duties, so that the coming year may be as successful as the one just closed.

Respectfully submitted,

WM. H. THORNE,
Director.

LIST OF GRADUATES, ETC., 1914–15.

MECHANICAL DRAWING.

Wilbur S. Austin
Frederick A. Bach
Branson Barnes
Henry J. Bohn
William H. Buchy
Frank Christen
Edwin S. Elder
Jonathan Geiger
Alfred R. Godfrey
Henry Graul
Thomas J. Hackett
Emery J. Hadik
Harry Haering
Joseph Hecking, Jr.
Robert B. McArdle
John McGinnis, Jr.
Vincent Martin
Theodore T. Marville, Jr.
John Morris, Jr.
Charles W. Paarz

Irvin M. Pfeiffer
George M. Pfundt
Edward J. Pritchard, Jr.
George Richter
Frank J. Sarlo
Charles Schneider
Welling G. Schrack, Jr.
James P. Shinn
Herbert Sommermann
Harry W. Whitson
Howard G. Zeyher

ARCHITECTURAL DRAWING.

John Clark Good
Fred Stadtler
Warren G. Tilton

FREEHAND DRAWING AND WATER COLOR

Howard A. Graul
Rufus Haley

MATHEMATICS.

Clarence E. Baittinger
John J. Bowen
Robert G. Cook
Arthur H. Eilitz
Albert Forster, Jr.
Henry Graul
Emery J. Hadik
Harry Haman
Frederick Heinze
Herbert Jayes
Samuel King
Leon Liberman
John McGinnis, Jr.
John G. Merkh
Thomas M. Morrissey
Abraham Perlman
Frank Powell
G. H. Pratley

MECHANICS.

William Keller
John A. Schneider
Raymond S. Wood
Albert F. Wunderlich

NAVAL ARCHITECTURE.

Lawrence Hoban
Ridgley Sweeney
Frederick C. Whitney

EDMONDS SCHOLARSHIPS.

WINTER AND SPRING TERMS.

George L. Dreeman, Drawing
Fred E. Miick, Mathematics
Joseph H. Ritchie, Drawing
William H. Stewart, Mechanics
George W. Williams, Jr., Drawing

BARTOL SCHOLARSHIPS.

DEPARTMENT OF DRAWING.

WINTER TERM.

Sophie Colles,* Freehand
Harry Haering, Mechanical

---

* Fourth Year.

Joseph Hecking, Jr.,
Mechanical
Vincent Martin,
Mechanical
Frank B. Otto,
Architectural
Fred Stadtler,
Architectural

SPRING TERM.

Ellis Ayars,
Mechanical
Charles W. Bowne,
Mechanical
Frank B. Otto,
Architectural
Charles Schneider,
Mechanical
Fred Stadtler,
Architectural
Alfred G. Windstein,
Freehand

THORN SCHOLARSHIPS.

WINTER TERM.

Fred W. Grube,
Mathematics
J. L. Starr,
Mechanics
Frederick C. Whitney,
Naval Architecture

SPRING TERM.

Raymond Mattis,
Mathematics
Herbert Rovno,
Mechanics
Lawrence Hoban,
Naval Architecture

MR. W. D. BALDWIN'S PRIZE.

DRAWING.

Harry Haering

MR. J. B. McCALL'S PRIZE.

MATHEMATICS.

John G. Merkh

MR. S. M. VAUCLAIN'S PRIZE.

MECHANICS.

Raymond S. Wood

MR. WILFRED LEWIS'S PRIZE.

MECHANICS.

E. Victor Cooley

NEW YORK SHIPBUILDING COMPANY'S PRIZE.

NAVAL ARCHITECTURE.

Frederick C. Whitney

ALUMNI ASSOCIATION OF THE FRANKLIN INSTITUTE'S PRIZES.

AWARDED TO GRADUATES.

Harry Haering,
Mechanical Drawing
Fred Stadtler,
Architectural Drawing
Sophie Colles,*
Freehand Drawing
John McGinnis, Jr.,
Mathematics
Albert F. Wunderlich,
Mechanics
Ridgley Sweeney,
Naval Architecture

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 7, 1915.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 7, 1915.

MR. G. H. CLAMER *in the Chair.*

The following reports were presented for first reading:

No. 2613.—Anderson's Rolled Gear Machine.

No. 2633.—Owens's Bottle Making Machine.

The following report was amended and adopted:

No. 2597.—Wheeler's Escalator. Edward Longstreth Medal of Merit to Mr. George A. Wheeler.

R. B. OWENS,
Secretary.

AWARD OF THE JOHN SCOTT LEGACY MEDAL AND PREMIUM.

The City of Philadelphia, acting on the recommendation of The Franklin Institute, has awarded the John Scott Legacy Medal and Premium to Herbert Alfred Humphrey, of London, England, and to Cav. Ing. Alberto Cerasoli, of Rome, Italy, for the Humphrey Pump, a device for raising water by the direct application of the explosive energy of a mixture of combustible gas and air. In the pump, the momentum of a moving column of water is utilized to draw in and compress in a suitable chamber a charge of the gas mixture whose explosion raises the water.

The first installation of a Humphrey Pump was made at Dudley Port, in England, in 1909. Three years later, four pumps, each having a capacity of 40,000,000 gallons per day, and one pump of 20,000,000 gallons per day, were installed by the London Metropolitan Water Board. Tests subsequently made on these pumps gave an average fuel consumption of 0.904 pound anthracite coal per pump horse power hour.

---

* Fourth Year.

AWARD OF THE EDWARD LONGSTRETH MEDAL OF MERIT.

The Edward Longstreth Medal of Merit has been awarded to the late Mr. George A. Wheeler for his Escalator. This invention is an inclined elevator for transporting persons from one level to another. It consists of an endless system of stairs or steps having risers and treads, together with top and bottom landings. A framework provided with tracks supports the stairs, and the system is driven by proper mechanism. Passengers are guided on and off the landings by suitable means for safety, and a travelling handrail is provided for comfort. The basic invention was first disclosed in a patent granted to Mr. Wheeler in 1892, and a number of patents were subsequently issued to him for improvements and developments.

SECTIONS.

Section of Photography and Microscopy.—A meeting of the Section was held in the Hall of the Institute on Thursday, March 25, at 8 P.M.

Dr. George A. Hoadley presided.

Mr. Louis E. Levy, member of the Institute, delivered a lecture, entitled "Recent Advances in the Techno-graphic Arts."

The speaker reviewed the progress of the techno-graphic arts from the time of the introduction of the photomechanical process of reproduction of drawings. He showed how this introduction preceded even that of the daguerreotype. He described the fundamental operations of the processes of photolithography, collotype, phototype, and stereotype work, giving examples of each by the aid of lantern slides. He then considered the half-tone processes and their applications, concluding with a description of the recent rotary photogravure method. During the course of his remarks, the speaker showed photographs of the principal workers in the field of mechanical reproduction of drawings and photographs, and reviewed the effect of the work of each on the progress of the art.

A rising vote of thanks was extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and of the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on Thursday, April 1, at 8 P.M.

Mr. H. F. Sanville presided.

Dr. G. F. Stradling, member of the Institute, presented a communication, entitled "Modern Theories of Magnetism."

Pierre Curie published, in 1895, the results of his experiments relating susceptibility of both dia- and paramagnetic substances to magnetizing force and to temperature.

Ten years later Langevin developed a theory of magnetism based on the modern conception of the atom,—that is, an atom consisting of rotating electrons. This agreed with the results of Curie's experiments.

Pierre Weiss extended Langevin's theory, and introduced the idea of a magnetic field within the magnetized substance resulting from the action of the elementary magnets composing it. The strength of this internal field is calculated to be enormous, in some instances reaching to millions of gausses.

Weiss, from a study of the saturation phenomena of ferromagnetic substances near the absolute zero, has been able to determine the magnetic moment of the individual atom in a number of cases. These moments, when compared, are found to be practically all whole-number multiples of a certain quantity. To this quantity he has applied the name "magneton." An atom of iron has a magnetic moment of eleven magnetons, while for an atom of nickel the same quantity in three magnetons. The experimenter suggests that the magneton is a constituent of the atoms of all kinds, just as are electrons.

A vote of thanks was extended the speaker.

Adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held in the Hall of the Institute on Thursday, April 8, 1915, at 8 P.M.

Mr. George R. Henderson, president of the Section, occupied the chair.

Mr. H. H. Quimby, C.E., Chief Engineer, Department of City Transit, Philadelphia, Pa., delivered a lecture, entitled "Rapid Transit Problems in Philadelphia." With the aid of numerous lantern slides the speaker conveyed an idea of the present directions and volume of transit in the city of Philadelphia and of the future needs of the city for greater facilities for quick and direct local transit. He reviewed the various proposals made to supply these needs, concluding with a detailed description of the plan recently recommended to City Councils for adoption. He illustrated the routes suggested in this plan and the types of structure, and explained the method of financing.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section of the American Institute of Electrical Engineers was held in the Hall of the Institute on the evening of Thursday, April 15, 1915, at 8 o'clock.

Mr. W. C. L. Eglin, president of the Institute's Section, occupied the chair.

Dr. Charles P. Steinmetz, Consulting Engineer, General Electric Company, Schenectady, N. Y., delivered a lecture, entitled "Control and Protection of Electric Systems," in which he discussed the nature of different disturbances to which electrical systems are exposed, such as excess current and voltage, abnormal and excessive frequencies, and considered methods of control, suppression, and elimination of these disturbances.

A vote of thanks was extended the speaker and the meeting adjourned.

WILLIAM E. BULLOCK,
Acting Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 10, 1915.)

LIFE.

MISS HARRIET BLANCHARD, 1511 Walnut Street, Philadelphia, Pa.
MR. F. LYNWOOD GARRISON, 1019 Clinton Street, Philadelphia, Pa.

(Stated Meeting, Board of Managers, April 14, 1915.)

RESIDENT.

MR. GOUVERNEUR CADWALADER, 1710 Locust Street, Philadelphia, Pa.
MR. SAMUEL LEONARD KENT, JR., Manayunk, Philadelphia, Pa.

NON-RESIDENT.

MR. E. G. EBERLE, 1004½ Commerce Street, Dallas, Texas.
MR. W. WALLACE MCKAIG, Cumberland, Md.
MR. JAMES H. WAHL, 44 West One Hundred and Thirty-Fourth Street, Whitestone, N. Y.
MR. DAVID H. WILSON, JR., Erie Railroad Company, 50 Church Street, New York, N. Y.

CHANGES OF ADDRESS.

COL. GEORGE L. ANDERSON, 975 Hamilton Avenue, Palo Alto, Cal.
MR. WILLIAM H. BALLS, Southern High School, Broad and Jackson Streets, Philadelphia, Pa.
MR. DANIEL CHRISTY, 4927 Haverford Avenue, Philadelphia, Pa.
MR. S. B. ECKERT, 2024 DeLancey Street, Philadelphia, Pa.
MR. A. D. EDGERTON, Gardiner, Douglas County, Ore.
MR. S. S. EVELAND, 1108 South Forty-seventh Street, Philadelphia, Pa.
MR. JOHN G. FELTON, 18 East Fulton Street, Gloversville, N. Y.
MR. J. KEARSLEY M. HARRISON, 127 Township Line, Jenkintown, Pa.
MR. DAVID W. JAYNE, Barrett Manufacturing Company, 17 Battery Place, New York, N. Y.
MR. WILLIAM B. KEEFER, care of American Rubber Reclaiming Company, 406 Rittenhouse Street, Germantown, Philadelphia, Pa.
MR. E. A. MULLER, 839 Mitchell Avenue, Avondale, Cincinnati, Ohio.
MR. F. W. SALMON, 516 Twentieth Street, Birmingham, Ala.
MR. L. H. THULLEN, 85 Hick Street, Brooklyn, N. Y.

NECROLOGY.

Philip Henry Holmes was born at Gardiner, Maine, in 1845, and was educated in the public schools of his native place. He was an artist and an inventor, and in the latter connection he devoted particular attention to the production of machines for making dry fibre for paper pulp, to the fibre stopper for bottles, the graphite bearing, and the water wheel. For his invention of the oilless graphite bearing he was awarded the Institute's Elliott Cresson Medal in 1892. He became a life member of the Institute in 1891.

Mr. Holmes died on March 28, 1915.

Colonel Mark Richards Muckle was born in Philadelphia in 1825, and died on March 30, 1915. He was educated in the public schools of this city, and at the age of seventeen entered the office of the *Philadelphia Public Ledger*, where he rose from the position of clerk to that of treasurer. His active connection with this newspaper continued for fifty-six years.

Colonel Muckle took a prominent part in public affairs at an early age. He became connected with the order of Odd Fellows and with the Masonic order, in both of which he rose to offices of the highest distinction. His ability to address audiences in German made him popular with the German societies in this country. For his able services to German relief organizations he was decorated by the Kaiser with the order of the Red Eagle.

He was the first to suggest the holding of the Centennial Exhibition, and he took an active part in helping to secure the location of the exhibition in Philadelphia.

Colonel Muckle became a member of the Institute in 1853.

Mr. T. Jefferson Cope, 3244 North Fifteenth Street, Philadelphia, Pa.
Mr. Stephen Darlington, 50 North Twenty-third Street, Philadelphia, Pa.

LIBRARY NOTES.

PURCHASES.

BAKENHUS, KNAPP AND JOHNSON.—The Panama Canal. 1915.
BRAGG, W. H.—Studies in Radioactivity. 1912.
COFFIN, J. G.—Vector Analysis. 1911.
CROFT, T.—Wiring of Finished Buildings. 1915.
DADOURIAN, H. M.—Analytical Mechanics. 1913.
DAWE, E. A.—Paper and its Uses. 1914.
DICKSON, L. E.—Elementary Theory of Equations. 1914.
EUCKEN, A., ed.—Die Theorie der Strahlung und der Quanten. 1914.
GALITZIN, B.—Vorlesungen über Seismometrie. 1914.
GREENHILL, A. G.—Applications of Elliptic Functions. 1892.
GRÜNWALD, J.—Raw Materials for the Enamel Industry. 1914.
HAUSMANN, E.—Telegraph Engineering. 1915.
HENDERSON, G. R.—Cost of Locomotive Operation. 1906.
HOWE, M. A.—Masonry. 1915.
LANDOLT AND BÖRNSTEIN.—Physikalisch-chemische Tabellen. 1912.
LAWS, B. C.—Stability and Equilibrium of Floating Bodies. 1914.
MATTHEWS, E. R.—Coast Erosion and Protection. 1913.
METCALF AND HARRISON.—American Sewerage Practice. 1915.
UNDERWOOD AND SULLIVAN.—Chemistry and Technology of Printing Inks. 1915.

GIFTS.

Ajax Manufacturing Company, Reference Book and Catalogue of Hot Metal Working Machines. Cleveland, Ohio, no date. (From the Company.)

American Society of Civil Engineers, Constitution and List of Members, 1915. New York, no date. (From the Society.)

American Tap and Die Company, Catalogue No. 5 of "Adamantine" Threading Tools. Greenfield, Mass., no date. (From the Company.)

Burrows, C. H., Text-book "Oxy-acetylene Welding and Cutting." No place, no date. (From the Vulcan Process Company, Minneapolis, Minn.)

Byers, John F., Machine Company, Catalogue No. 21 of Hoisting Equipment. Ravenna, Ohio, no date. (From the Company.)

Canada Department of Mines, "Report on the Non-metallic Minerals Used in the Canadian Manufacturing Industries," "Peat, Lignite, and Coal." Ottawa, 1914. (From the Department.)

Canada Department of Public Works, Minister's Report, vol. 1, 1914. Ottawa, 1915. (From the Department.)

Central University of Kentucky, Catalogue of The Centre College, 1914–15. Danville, no date. (From the University.)

Connecticut Public Utilities Commission, Report, 1914. Hartford, 1915. (From the Commission.)

Cutter, George, Company, General Catalogue No. 12 of Electrical Lighting and Wiring Devices. South Bend, Ind., no date. (From the Company.)

Delaware College, Annual Catalogue, 1914–15. Newark, Del., no date. (From the College.)

Deming Company, Catalogue J of Pumping Machinery. Salem, Ohio, no date. (From the Company.)

Harbison Walker Refractories Company, "A Study of the Malleable Furnace." Pittsburgh, Pa., no date. (From the Company.)

Hobart College, Catalogue 1914–15. Geneva, N. Y., 1915. (From the College.)

Illinois State Geological Survey, Bulletin No. 29, "Purchase and Sale of Illinois Coal on Specification." Urbana, 1914. (From the Survey.)

Kaiser, J., "Systematic Indexing," The Card System Series, vol. ii. London, 1911. "Le Systeme de la Carte au Bureau." Paris, 1914 (From the Author.)

Kentucky Geological Survey, Report, series iv, vol. ii, part 1. Frankfort, 1914. (From the Survey.)

Limbert, George B., & Company, Catalogue C of Steam Goods. Chicago, 1915. (From the Company.)

Main, Charles T., Industrial Plants, vol. ii. Boston, no date. (From Mr. Charles T. Main.)

Maple City Manufacturing Company, General Catalogue No. 14 of Oilers. Monmouth, Ill., no date. (From the Company.)

Michigan Board of Agriculture, Report. Lansing, 1914. (From the Board.)

Milwaukee Concrete Mixer Company, Catalogue of Mixers and Pavers. Milwaukee, Wis., no date. (From the Company.)

Music Trades Company, "The Piano and Organ Purchaser's Guide for 1915." New York, no date. (From the Company.)

Mysore Meteorological Department, Report on Rainfall Registration, 1913. Bangalore, India, 1914. (From the Department.)

National Lamp Works, Bulletin of Engineering Department on Illumination. No place, no date. (From the Works.)

New Bedford Water Board, Forty-fifth Annual Report, 1914. New Bedford, Mass., 1915. (From the Board.)

New York Bureau of Explosives, Report of the Chief Inspector, New York, 1915. (From Col. B. W. Dunn.)

New York, New Haven and Hartford Railroad Company, Forty-third General Statement. New Haven, 1914. (From R. D. Jenks, Esq.)

North Carolina Geological and Economic Survey, Biennial Report of the State Geologist, 1913–14. Raleigh, 1915. (From the Survey.)

Pennsylvania Adjutant-General, Report, 1910. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania Commissioners of Sinking Fund, Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Department of Grand Army of the Republic, Forty-eighth Annual Encampment. Harrisburg, 1914. (From the State Librarian.)

Pennsylvania State Librarian, Report, 1914. Harrisburg, 1915. (From the State Librarian.)

Pennsylvania Water Supply Commission, 1913. Harrisburg, 1914. (From the State Librarian.)

Raymond Brothers Impact Pulverizer Company, Catalogue No. 11 of Grinding, Pulverizing and Separating Machinery. Chicago, 1914. (From the Company.)

Republica Oriental del Uruguay, Anuario Estadistico, Anos 1909–10. Montevideo, 1914. (From the Director General.)

Springfield Board of Water Commissioners, Forty-first Annual Report, 1914. Springfield, Mass., 1915. (From the Board.)

Steel Company of Scotland, Section Describing Manufactures. Glasgow, 1913. (From the Company.)

Street, R. R., & Company, Incorporated, Catalogue No. 15 of Modern Approved Appliances for the Transmission of Power, Machine Shop Specialties. Chicago, no date. (From the Company.)

Sydney University Engineering Society, Proceedings, 1912. Sydney, N. S. W., no date. (From the Society.)

U. S. Naval Observatory, The American Ephemeris and Nautical Almanac, 1917. Washington, 1915. (From the Observatory.)

University of Illinois, Report. Urbana, 1914. (From the University Library.)

University of North Dakota, General Catalogue, 1914–15. University, no date. (From the University.)

University of Virginia, Catalogue, 1914–15. Charlottesville, 1915. (From the University.)

Vermont Attorney-General, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Board of Education, Report. Montpelier, 1914. (From the State Librarian.)

Vermont Lake Champlain Tercentenary Commission, Final Report. Montpelier, 1914. (From the State Librarian.)

Vermont Commissioner of Agriculture, Sixth Annual Report. Montpelier, 1914. (From the State Librarian.)
Vermont Commissioner of Taxes, Report. Montpelier, 1914. (From the State Librarian.)
Vermont Factory Inspector, Report. Montpelier, 1914. (From the State Librarian.)
Vermont Free Public Library Commission, Tenth Report. Montpelier, 1914. (From the State Librarian.)
Vermont Legislative Directory. Montpelier, 1915. (From the State Librarian.)
Vermont Soldiers' Home, Report. Montpelier, 1914. (From the State Librarian.)
Vermont Permanent School Fund, Fourth Report. Montpelier, 1914. (From the State Librarian.)
Vermont Public Documents. Montpelier, 1914. (From the State Librarian.)
Vermont Public Service Commission, Fourteenth Report. Montpelier, 1914. (From the State Librarian.)
Vermont State Board of Health, Report. Montpelier, 1913. (From the State Librarian.)
Vermont State Board of Medical Registration, Fifth Report. Montpelier, 1914. (From the State Librarian.)
Vermont State Highway Commissioner, Eighth Report. Montpelier, 1914. (From the State Librarian.)
Vermont State Geologist, Report. Montpelier, 1914. (From the State Librarian.)
Vermont State Hospital for the Insane, Thirteenth Report. Montpelier, 1914. (From the State Librarian.)
Vermont State School of Agriculture, Second Report. Montpelier, 1914. (From the State Librarian.)
Vermont Superintendent of Education, Forty-third Report. Montpelier, 1915. (From the State Librarian.)
Vermont Supervisors of the Insane, Report. Montpelier, 1914. (From the State Librarian.)
Vidal, Leon, Traite Pratique de Photochromie. Paris, 1903. (From Mr. Lucien E. Picolet.)
Whiting Foundry Equipment Company, General Catalogue of Cranes and Air Hoists. Harvey, Ill., no date. (From the Company.)
Williams, J. H., & Company, Catalogue of Iron, Steel, Copper, Bronze, and Aluminum Drop-Forgings. Brooklyn, no date. (From the Company.)
Yale University, General Catalogue, 1914–15. New Haven, 1915. (From the University.)

PUBLICATIONS RECEIVED.

Hancock's Applied Mechanics for Engineers, revised and rewritten by N. C. Riggs, Professor of Theoretical and Applied Science in the Carnegie Institute of Technology. 441 pages, illustrations, 12mo. New York, The Macmillan Company, 1915. Price, $2.40.

Chemistry of Familiar Things, by Samuel Schmucker Sadtler, S.B. 320 pages, illustrations, plates, 8vo. Philadelphia, J. B. Lippincott Company, no date. Price, $1.75.

Canada Department of Mines, Mines Branch: Peat, Lignite and Coal: Their Value as Fuels for the Production of Gas and Power in the By-product Recovery Producer, by B. F. Haanel, B.Sc. 261 pages, illustrations, tables, plates, maps, 8vo. Report on the Non-metallic Minerals Used in the Canadian Manufacturing Industries, by Howells Fréchette, M.Sc. 199 pages, tables, 8vo. Ottawa, Government Printing Bureau, 1914.

Pennsylvania Topographic and Geologic Survey: Biennial Report for the two years ending June 1, 1914. 232 pages, maps, 8vo. Harrisburg, State Printer, 1914.

Carnegie Institution of Washington: Annual Report of the Director of the Department of Terrestrial Magnetism. [Extracted from the Year Book No. 13 for the year 1914, pp. 298–332, plates 5, 6, 7.] 37 pages, illustrations, map, 8vo. Washington, no date.

Mineral Resources of the Philippine Islands for the Year 1913. Issued by the Division of Mines, Bureau of Science. 71 pages, illustrations, plates, map, 8vo. Manila, Bureau of Printing, 1914.

U. S. Bureau of Mines: Technical Paper 99, Probable Effect of the War in Europe on the Ceramic Industries of the United States, by A. S. Watts. 15 pages, 8vo. Washington, Government Printing Office, 1915.

U. S. Bureau of Standards: Circular No. 35, 2d edition, Melting-points of Chemical Elements, and Other Standard Temperatures. 2 pages, 8vo. Washington, Government Printing Office, 1915.

Calorimetric Methods. W. P. WHITE. (*Amer. Chem. Soc. Journ.,* xxxvi, 2313.)—This is the last of a series of papers on calorimetric measurements. In the "Method of Mixtures" a precision approaching or reaching 0.1 per mille, though somewhat unusual, is often desirable. The author describes its attainment as especially easy with a two-calorimeter installation, which secures the convenience and high precision of differential thermo-electric temperature measurement. This is the only advantage of the two-calorimeter arrangement, the diminution of heat-loss error being largely illusory. If instead a vacuum-jacketed flask is used for the comparison calorimeter, there is a gain in accuracy and convenience. The necessary temperature observations may be made as simple as with the twin-calorimeter arrangement by means of a special thermo-electric combination. A completely enclosing jacket of uniform temperature is necessary for this method, but this is no loss, as such a jacket is necessary for high precision with any method. This method is quite as effective with a jacket round each calorimeter, and therefore with adiabatic methods. The present method is especially advantageous for observations of great absolute precision and for use in cases where rapidity and facility in making varied observations are required.

CURRENT TOPICS

Tests of Vanadium Steel Rails. (*Eng. Record,* lxx, 450.)—The American Vanadium Steel Company has had several heats of basic open-hearth steel, to which vanadium has been added, rolled into rails for purposes of test. It has been found that the addition of vanadium to rail steels increases the elastic limit, the ductility, resistance to alternating stresses, hardness, and resistance to wear. Its use does not demand any alteration in the rolling-mill practice; in fact, the yield of rails from the ingots is likely to be increased owing to a decreased tendency towards cracking and tearing in the rolls. Compared with ordinary, plain carbon steels, vanadium steel shows a lessened tendency to segregate, resulting in a denser and more uniform product. The most suitable percentage composition for vanadium rail steels is as follows: Carbon, 0.45 to 0.60; Si, over 0.10; Mn, 1.00 to 1.25; P, not over 0.05; S, not over 0.05; V, an addition of 4 pounds per gross ton.

By the addition of vanadium it is possible to use rail steels of lower carbon content, which will reduce the danger of the production of internal fissures in rolling.—*The Iron Age.*

Electrolytic Oxygen in St. Louis. ANON. (*Sci. Amer.,* cxii, No. 2, 47.)—A number of plants in St. Louis, Mo., are producing commercial oxygen electrolytically. A ten to fifteen per cent. solution of potassium hydroxide or sodium hydroxide is employed. Through this a current of electricity is passed, and the oxygen that collects at one electrode is trapped and led off to a compressor, while the hydrogen is permitted to escape. If we, in this country, showed anywhere near the aëronautic activity of European countries the hydrogen would also be collected and used for the inflation of balloons.

The Most Powerful Electric Passenger Locomotive. ANON. (*Sci. Amer.,* cxi, No. 25, 503.)—During the year sixteen powerful electric passenger locomotives have been placed in service on the main lines of the New York Central Railroad. They are the most powerful electric passenger locomotives in existence, and each is capable of hauling a train of fourteen steel Pullman cars continuously at a sustained speed of sixty miles per hour; while with lighter trains a maximum speed has been attained with these locomotives of eighty-five miles per hour; these speeds have been accomplished frequently on the experimental track of the company near Schenectady. All the wheels of the locomotives, including those on the leading and trailing trucks, carry motors the whole weight being thus available for producing tractive effort.

Rolling-mill with Geared Turbine Drive. (*Mech. Eng.*, xxxiv, 492.)—This article, illustrated with plan and elevation, describes the first geared turbine to drive a rolling-mill in America, the only one previous to this being at the works of J. Dunlop & Co., Calderbank, Scotland, where a 750-horse-power, mixed-pressure turbine operates at 2000 r. p. m. with two-stage reduction to 375 and 70 r. p. m. The maximum loss in the gear is said to be less than 2 per cent. At the Carpenter Steel Company's works, Reading, Pa., a three-high roughing mill was formerly driven by a 36 x 36-inch simple slide-valve condensing engine at 60 to 100 r. p. m. A mixed-pressure turbine has now been installed in place of the engine, designed to work on the exhaust of a 22-inch and 40 x 48-inch stroke, cross-compound engine which drives one 8-inch and two 10-inch finishing mills by belt. When working on exhaust steam at 3 pounds per square inch and 27 inches vacuum the turbine is to develop 350 horse-power at 70 to 100 r. p. m. at the mill shaft, and is not to take more than 26 pounds of steam per b.h.p.-hour measured after second gear reduction. At 120 pounds pressure the steam consumption at 350 b.h.p. is not to exceed 17½ pounds per b.h.p.-hour. On both high- and low-pressure steam 600 b.h.p. is to be developed, and on high-pressure steam only 600 horse-power must be the output, with not more than 15.7 pounds steam per h.p.-hour.

The reduction gear is two-stage, double-helical, reducing from 5000 to about 500 r. p. m. and then to between 60 and 100 r. p. m. The gear teeth are involute, 45° angle, cut in rolled steel bands shrunk on cast-iron centres; the pinions are chrome-nickel steel forgings. The engine fly wheel, weighing 47,600 pounds, was left in place, and the connecting rod only removed. A distance piece, which also serves as a flange of the flexible coupling, was bolted to the crank disk. A multi-port valve adjacent to the turbine l. p. throttle prevents vacuum from backing up into the engine exhaust, and so prevents air being drawn in through glands and interfering with condenser action. The condenser is of the Schutte-Körting multi-jet type, with automatic relief to atmosphere; with water at 72° F. it maintains 28.2 inches vacuum (bar 29.78 inches). The cost of the turbine gear, condenser, piping, circulating pump, valves, etc., was approximately £5000, including erection. The saving through better economy by its use has been about £3000 per annum.

Transformation of Yellow into Red Phosphorus. KUSPERT. (*Z. Physik. Chem. Unterricht*, xxvii, 102.)—A minute particle of phosphorus is placed on a thin layer of candle tallow on a microscopic slide, and over this is placed a cover-glass. This is gently heated; the phosphorus melts, sinking into the tallow. After concentrating light upon the phosphorus the color is seen through the microscope gradually to change first to orange, then to red. This is accompanied by a melting of the tallow, which shows that an exothermal change takes effect.

Production of Neon and Helium by the Electric Discharge. J. N. COLLIE and H. S. PATTERSON and I. MASSON. (*Roy. Soc. Proc.*, Ser. A, xci, 30.)—Elaborate tests have been made with special forms of discharge tube. A few of these are described with the aid of diagrams. A great many of the experiments yielded negative results, for as yet unexplained reasons. Tentative suggestions are made as to why Strutt's work proved unsuccessful, and it is noted that Strutt's results are in opposition not only to many of the results obtained by the present authors, but also to those of J. J. Thompson, which appear substantially to corroborate the authors' results by an independent method. Although the source of the helium and neon has not been as yet discovered, it appears, from careful experiments now made, fairly certain that these gases were not previously contained in the materials of the tubes; and other experiments show that permeation from the air through the walls of the discharge tubes appears to be equally improbable.

Tests of Substitutes for Gasoline (*Petrol*). J. A. MOYER. (*Power*, xl, 569.)—Generally speaking, gasoline or petrol is the only fuel used for automobiles, while enormous quantities are required for farm tractors, as well as for stationary and marine engines of all types. The investigations described by the author were conducted during the past year at the Engineering Experiment Station of the Pennsylvania State College to determine the applicability of (1) paraffin, (2) alcohol, (3) motor spirit, and (4) mixtures of petrol and paraffin as substitutes for petrol in engines. Most important results as regards the effect of the injection of water and air on the capacity and the economy of the engines were also obtained, and tests and experiments to determine the underlying reasons for the peculiar action of this water, when sprayed into the combustible mixture before it enters the cylinder, are being continued. The tests were made on a four-stroke-cycle stationary type of water-cooled engine, designed particularly for operation with petrol. The cylinder bore was 6¾ by 10-inch stroke, and governing was by the "*hit and miss*" method.

The primary object was to determine the maximum power and fuel consumption for each of the fuels used, first without injecting water into the fuel-intake pipe, and later with water injection. It is well known that the injection of water is effective in preventing so-called pre-ignition, especially with fuels like paraffin, which is prone to produce excessive "*pounding*" in the cylinder when running under heavy load. It has been contended that the water injected with the fuel, since it becomes superheated steam, would have a beneficial effect, both as regards the maximum power obtained and the fuel consumption. The tests showed that the maximum horsepower of the engine was considerably increased, especially when paraffin was used for fuel, but in all cases with a sacrifice of economy;

that is, the fuel consumption per horse-power-hour was considerably greater with water injections. These tests were made with a carburettor in which the fuel was discharged under pressure in a fine vapor from a special spraying device. The carburettor was effectively heated with the exhaust gases, and after the engine was once heated uniformly its operation was little affected by varying the amount of heating of the mixture in the carburettor.

The amount of water injected was regulated by hand and a needle valve, in every case just enough being injected to prevent unusual pounding. Ignition-timing in this series was practically the same for all tests. Details are then given of the test results with and without water injection: (1) with paraffin, (2) with petrol and paraffin mixed in equal proportions, (3) with motor spirit, (4) with petrol, (5) with alcohol.

Alcohol as a Substitute for Benzine for Driving Motor Cars. W. HEMPEL. (*Z. Angew. Chem.*, xxvii, 521.)—In 1912 Germany produced 179,800 tons (metric) of benzine; in 1913, 160,000 tons of benzol, of which 50,000 tons were exported to France; and in 1912–1913, 3,753,265 hl. of alcohol. All motor cars in Berlin have been adapted to use alcohol as well as benzine. The following are the respective heats of combustion of the different substances tried in the experiments: Benzine, 9500–10,500; pure benzol, 10,260; commercial ninety per cent. benzol, 9550–10,000; pure alcohol, 7402; ninety-five per cent. alcohol, 5875; and pure naphthalene, 9628.3 Calories per kilogramme. Alcohol denatured with one to twenty per cent. of benzol is much more suitable for motor engines than that containing wood alcohol or pyridine. According to Dieterich, a mixture of one volume of petroleum spirit with two volumes of benzol is particularly suitable for this purpose. After suitable regulation of the tubes of a Lyma carburettor the following mixtures could be used: (1) a mixture of four volumes of ninety-five per cent. alcohol and one volume of ninety per cent. benzol containing 200 grammes of naphthalene per litre; (2) four volumes of ninety-five per cent. alcohol and one volume of crude benzol containing 200 grammes of naphthalene per litre; (3) four volumes of ninety-five per cent. alcohol and one volume of light coal-tar oil containing 200 grammes of naphthalene per litre. In a long run eighteen litres of mixture No. 1 gave the same result as fifteen litres of ordinary petrol. Only oils purified by sulphuric acid and alkali should be used for this purpose. There is also a possibility of using a solution of acetylene in acetone (which dissolves thirty-one volumes) or alcohol (six volumes). The use of pure alcohol tends to produce rust in the engine.

Cutting and Welding with the Oxyacetylene Torch. ANON. (*Amer. Mach.*, xlii, No. 8, 316.)—In a general review of the process of oxyacetylene cutting and welding delivered before the Illinois

Gas Association it is stated that from the standpoint of volume of work done by this process America leads, with Germany second, France third, and England fourth. In scientific research and special development Germany leads all other countries. This is partly due to the fact that the German government has established schools at various places where the art is taught as one of the applied sciences. As one feature of the work being carried on in Germany, it might be mentioned that piping of all sizes and character is now being made by rolling from flat plate and welding by means of the oxyacetylene torch. Piping is also being laid without the use of threads or flange joints. In this way they are enabled to use pipe of about one-half the thickness of our standard pipe, thereby saving greatly in material costs. To show what the German government thinks of this class of work, it is merely necessary to mention that at Cologne, in the Palace of Justice building, recently completed, there are nearly seven miles of piping in which there is not a single threaded joint, all being welded by oxyacetylene.

Static Electricity from Friction. ANON. (*Amer. Mach.*, xli, No. 18, 780.)—The production of static electricity by friction of pulleys and belts has been assigned as the cause of recent dust explosions. Although experiments have not been conducted along this line to show that a dust cloud can be ignited in this manner, a recent experiment at Pittsburgh showed very clearly that sufficient static electricity could be produced by a very small pulley and shaft to ignite gas readily. A milling company in Texas, engaged in grinding cotton-seed cake into meal, states that after experiencing a series of explosions the insulating of a certain grinding machine prevented any repetition of previous occurrences. The fact that explosions have been known to occur at times when the feed of grinding machines was cut off seems to indicate that an unknown factor may be the responsible agent. A series of experiments is being planned under the direction of the U. S. Bureau of Mines in order to determine if static electricity can produce ignition of the dust while in suspension. A preliminary report on the explosibility of grain dusts has already been published by the Bureau.

Cement from Beets. ANON. (*Sci. Amer.*, lxxix, No. 2038, 61.)—A French firm is making an excellent cement from a by-product in the process of making beet-sugar. The scum that forms when the beets are boiled, and which has heretofore been thrown away, consists largely of calcium carbonate and water, and from 70,000 tons of beets treated 4000 tons of calcium carbonate are obtained; to this 1100 tons of clay are added, the resulting product being 3162 tons of excellent cement. The partially-dried scum is mixed with finely-divided clay, amalgamated by beaters, and burned in a rotary kiln.

Ultraviolet Rays for Vulcanizing Rubber. ANON. (*Sci. Amer.*, cxi, No. 25, 503.)—Dissolved rubber can be vulcanized without using heat, and can be kept in a semi-liquid state, although vulcanized, by a new method discovered by a German chemist, Dr. M. Heilbronner. Rubber is dissolved in a light hydrocarbon solvent, in the proportion of fifteen parts of solvent to one of crude rubber. A solution of crystallized sulphur in benzine is then added to the rubber solution and the mixture is subjected to ultraviolet rays from a Cooper-Hewitt mercury vapor lamp in quartz tubes. The rubber in the solution combines with the sulphur, and when the solvent is allowed to evaporate the residue is pure vulcanized (insoluble) rubber. For repairing, the vulcanized solution is used and the solvent is evaporated, giving a sort of "autogenous rubber welding" which fails to disclose the points of contact. When two rubber surfaces are joined by this vulcanized rubber solution a homogeneous mass is formed.

The "Concentrated Filament" Lamp. (*Elect. Rev. and West. Electn.*, lxv, 1013.)—This relates to tungsten filament lamps, which are suitable for projection purposes or for headlights, etc. It is said that a six-volt battery lamp, of 108 watts capacity, will yield over 900,000 candle-power if furnished with a 20-inch parabolic reflector of the silver-plated type. These lamps are said to be used for a great variety of purposes.

PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA